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Muscle Responses to High-Intensity Eccentric Exercise : A Comparison Between Untrained and Highly Resistance-Trained Subjects

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USE OF THESIS

MUSCLE RESPONSES TO HIGH-INTENSITY ECCENTRIC EXERCISE: A COMPARISON BETWEEN UNTRAINED AND HIGHLY RESISTANCE-TRAINED SUBJECTS

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ABSTRACT

Eccentric exercise, which is when the muscle produces force as it lengthens, has been shown to result in decrements to muscle functions. This study was designed to investigate whether there was a difference between the muscle responses of untrained (n = 8) and resistance-trained (n = 8) individuals after a bout of high-intensity eccentric exercise of the elbow flexors. All subjects were males aged 18 to 45 years and recruited based on specific training criteria.

Subjects performed 10 sets of 6 maximal eccentric contractions of the elbow flexor muscles on an isokinetic dynamometer. 10 seconds rest was provided between each repetition and 3 minutes rest between each set of the exercise protocol. The exercise bout resulted in significant ($p<0.05$) decreases in range of motion and maximal isometric and isokinetic concentric strength for both trained and untrained groups. However, as hypothesised the trained group recovered these muscle functions more quickly than the untrained group did. The untrained group also showed larger ($p<0.033$) increases in arm circumference than the trained group did. Although significant ($p<0.05$) levels of soreness and tenderness were experienced by both groups following the eccentric exercise, there was no difference between the two groups.

The results from this research suggest that resistance-training provides a protection against exercise-induced muscle damage and results in a faster recovery of muscle function after a bout of high-intensity eccentric exercise.

DECLARATION

I certify that this thesis does not, to the best of my knowledge and belief:

(i) incorporate without acknowledgment any material previously submitted for a degree or a diploma in any institution of higher education;

(ii) contain any material previously published or written by another person except where due reference is made in the text; or

(iii) contain any defamatory material.

Signature .....[redacted]............

Date ..21/2/02..............

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There are many people without whom this research, and year in general, would not have been completed. I can only hope that each of these people know how much their efforts have been appreciated. In the interest of keeping this section as short as possible I will not list every individual's name, but in the process I hope that I do not forget to mention a group of people who deserve to be included. Anyway, here goes:

Firstly, to Paul Sacco and Kazunori Nosaka, my supervisors, thank you for your guidance (I needed a lot of it!) and promptness in returning all queries that I made to either of you.

Very importantly, I give a big 'cheers' to all the people who participated in this study. Thanks for donating your time and effort for no material reward and for being so willing to make it as easy as possible for the researchers. I hope that you all enjoyed participating in the study despite the pain that you may have endured. You were all a pleasure to work with, therefore, collecting the data never felt like a chore.

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Introduction

1.1 Background to the Study

Excessive and repetitive loads on muscles, as experienced in a resistance-training bout, can result in damage to the muscle tissue. It has been established that eccentric muscle actions produce more severe muscle soreness, cellular disruption and swelling than exercise involving concentric-only contractions (Gibala et al., 2000; Ploutz-Snyder, Tesch, & Dudley, 1998). Although muscles are damaged from eccentric actions, they have considerable powers of regeneration (Jones & Round, 1990, p. 171). Not only do muscles recover their function following damaging bouts of eccentric exercise, they have also been shown to result in adaptations, which protect the muscle from further damage during subsequent exercise bouts (Clarkson, Nosaka, & Braun, 1992; Paddon-Jones, Muthalib, & Jenkins, 2000; Prou, Guevel, Benezet, & Marini, 1999).

It is also believed that the greater strain put on the neuromuscular system with eccentric exercise is vital in achieving optimal gains in muscular strength and size (Ploutz-Snyder et al., 1998). For this reason athletes attempting to further their performance or progress from a plateau in their training often use heavy eccentric contractions. However, the greater degree of damage to the muscle tissue as a result of eccentric activation of muscles is associated with a prolonged time course for recovery (Clarkson et al., 1992). Because fitness professionals and coaches often need to keep athletes 'on the track', rest/recovery is arguably one of the more important factors in planning a long-term training program. However, the vast majority of data that has been gathered regarding recovery after a bout of damage-inducing exercise involves untrained subjects. Therefore, data on the recovery from eccentric exercise-induced muscle damage gathered from subjects who are highly resistance-trained would be beneficial in the understanding of the likely effect eccentric exercise would have on physical performance.

The magnitude of microtrauma to a muscle is difficult to assess quantitatively, therefore it is more commonly estimated by measures of muscle function (Ploutz-Snyder et al., 1998). Quantitative assessment of muscle damage requires the invasive procedure of obtaining muscle biopsies. To this end, the present research has focused on the functional aspects of the exercised muscle together with other indirect indices of muscle damage, such as soreness.

1.2 Significance of the Study

Based upon prior research it is generally accepted that the inclusion of an eccentric component to a training program is important if maximum gains in strength are to be realised (Colliander & Tesch, 1990; Ploutz-Snyder et al.. 1998). Training with eccentric actions, however, can result in profound decrements in muscle function and a protracted recovery period, which would be likely to have an effect on sporting performance. To date, the majority of the research focusing on the effects of eccentric actions has been undertaken using untrained subjects. Most studies that have involved trained subjects have recruited previously untrained subjects who have completed short term training programs in which neural adaptations predominate, rather than physiological adaptations at the muscular level (McArdle, Katch, & Katch, 1996, p.440). Therefore, the results from past research are not entirely applicable to coaches whose athletes are involved in resistance training. If there were to be a difference between the time courses of recovery for untrained subjects versus those who had a background in resistance training then this data would be valuable in more accurately periodising training programs for athletes.

1.3 Purpose of the Study

The purpose of this study was to determine whether resistance-trained subjects differ in response to a damaging bout of exercise of the elbow flexor muscles compared to untrained subjects. The dependent variables were plasma creatine kinase (CK) concentration and changes in strength, range of motion, arm circumference and soreness and tenderness of the exercised muscle.

1.4 Hypotheses/ Research Questions

It was hypothesised that:

1. The maximal voluntary isometric and dynamic torques of the elbow flexors would recover more quickly for trained (T) than for untrained (UT) subjects following the bout of eccentric exercise.
2. T subjects would experience less soreness than UT subjects following the bout of eccentric exercise.
3. UT subjects would experience a greater magnitude of swelling than T subjects following the bout of eccentric exercise.
4. UT subjects would show greater decreases in range of motion (ROM) about the elbow joint than T subjects following the eccentric exercise.
5. UT subjects would produce a larger elevation in plasma CK concentration than T subjects following the bout of eccentric exercise.

1.5 Definitions of Terms

ANOVA	Analysis of variance.
CK	Creatine kinase.
Eccentric contraction	A contraction during which the muscle lengthens whilst producing tension.
Isometric contraction	A contraction during which a muscle produces force with no overall change in its length.
Concentric contraction	A contraction during which a muscle shortens as it produces force.
Isokinetic dynamometer	A device used to measure the torque output of isokinetic muscle contractions at any of a number of velocities.

Torque	A measure of angular force. Units are expressed in Newton-metres (Nm).

Chapter 2

Review of Literature

2.1 Muscle Damage

2.1.1 Initial Causes

It is believed that the initial causes of exercise-induced muscle damage relate to mechanical and/or metabolic origins (Appell, Soares, & Duarte, 1992; Armstrong, Warren, & Warren, 1991). Proposed metabolic initiating events of muscle damage include insufficient mitochondrial respiration, oxygen free radical production and lowered pH (Armstrong, 1990; Evans, 1987), but because eccentric contractions require less energy expenditure than concentric or isometric contractions these explanations are not widely accepted. A more plausible metabolic explanation is that the intramuscular temperature is higher during eccentric work than during concentric work (Appell et al., 1992; Armstrong et al., 1991; Clarkson & Sayers, 1999; Evans, 1987). Increased temperatures may cause degradation of proteins and decrease the viscosity of the sarcolemma, which would increase the rate of membrane degradation (Armstrong et al., 1991). Muscle cells can also synthesise stress proteins (also known as heat shock proteins) with increases in (Clarkson & Sayers, 1999). The exact function of these proteins is yet to be determined but they act in both the denaturation and degradation of proteins as well as protein synthesis and the restoration of function of damaged proteins (Clarkson & Sayers, 1999).

Not only do eccentric muscle actions require less energy than isometric or concentric contractions, but they can produce higher forces than concentric and isometric contractions (Jones & Round, 1990, p. 164) with fewer motor units recruited (Armstrong, 1984; Clarkson & Sayers, 1999; Enoka, 1996; Foley, Jayaraman, Prior, Pivarnik, & Meyer, 1999). This means that the force is spread over a smaller cross-sectional area of the muscle during eccentric contractions and the active fibres may be placed under excessive strain (Armstrong, 1984; Clarkson & Sayers, 1999; Foley et al., 1999). Therefore, mechanical factors are more likely to initiate muscle damage resulting from eccentric exercise (Appell et al., 1992; Clarkson & Sayers, 1999).

It has been proposed that sarcomeres occur at differing lengths throughout a muscle fibre and that when a muscle undergoes an eccentric contraction sarcomeres elongate in a non-uniform manner (Clarkson, 1997; Morgan & Allen, 1999; Whitehead, Allen, Morgan, & Proske, 1998). The weaker sarcomeres may stretch beyond their point of being able to maintain tension through crossbridge attachment and "pop". With additional contractions there would be less active sarcomeres able to produce tension and this would lead to more sarcomeres being stretched beyond their yield point and popping. With more and more sarcomeres unable to supply tension and dissipate force during the lengthening contractions, the connective tissue in the muscle, the sarcolemma, sarcoplasmic reticulum and t-tubules, will come under tensile stress and rupture (Armstrong et al., 1991; Clarkson & Sayers, 1999; Morgan & Allen, 1999; Whitehead et al., 1998).

Another area where the mechanical stresses appear to have an effect on the fibres is at the Z-line (Appell et al., 1992; Clarkson, 1997; Evans, 1987; Jones & Round, 1990). The Z-line is thought to be a weak link in the network of contractile filaments and it has been shown that eccentric contractions result in lesions at the Z-line known as "Z-line streaming" (Appell et al., 1992; Armstrong, 1990; Evans, 1987). It is believed that the Z-lines will suffer stresses after sarcomeres are popped because they transmit tension to neighbouring, active sarcomeres (Morgan & Allen, 1999).

Whatever the initial causes of eccentric exercise-induced muscle damage, resulting loss of Ca^{2+} homeostasis and influx of these ions into the muscle cell marks the beginning of the autogenetic phase.

2.1.2 Autogenetic phase

Once the muscle cell has lost its structural resilience the influx of Ca^{2+} initiates a number of degradative pathways (Armstrong et al., 1991; Clarkson & Sayers, 1999). One proposed pathway for developing further damage in the muscle is through the action of calcium-activated neutral proteases. Calpain, one such protease, has been implicated in the degradation of the proteins desmin, vimentin, synemin and α-actinin (Clarkson & Sayers, 1999; Sorichter, Puschendorf, & Mair, 1999). Desmin, vimentin and synemin are responsible for attaching neighbouring myofibrils at the Z-line and α-actinin is the protein that anchors actin to the Z-line (Clarkson & Sayers, 1999; McArdle et al., 1996).

Phospholipase A_2 (PLA_2) is another calcium-activated enzyme found within the muscle fibre (Armstrong et al., 1991; Jones & Round, 1990, p. 160). This enzyme is also thought to cause damage to the fibre indirectly. PLA_2 produces lysophospholipids, which affect the stability of the fibres by dissolving the cell membranes and liberating free fatty acids, including arachidonic acid (Armstrong et al., 1991; Jones & Round, 1990, p.161). The liberated free fatty acids are then metabolised and free oxygen radicals are produced. The free oxygen radicals also cause injury to the sarcolemma (Armstrong, 1990; Jones & Round, 1990, p. 161). Another hypothesised source of the oxygen free radicals is from oxygenated blood entering the damaged muscle as capillaries move back into the area of regeneration (Clarkson & Sayers, 1999; Jones & Round, 1990, p. 161). This is known as reperfusion injury (Clarkson & Sayers, 1999). Arachidonic acid may also be involved in protein degradation (Armstrong et al., 1991).

With the influx of Ca^{2+} ions into the muscle fibres after the initiating events of muscle damage, there is an accumulation of theses ions in the mitochondria (Appell et al., 1992; Armstrong et al., 1991; Evans & Cannon, 1991). Excessive amounts of Ca^{2+} in the mitochondria will disrupt cellular respiration and this will activate proteolytic enzymes, which will degrade the contractile structures of the fibre (Appell et al., 1992).

2.1.3 Phagocytic Phase

The phagocytic phase usually begins 3 to 4 hours after the damaging exercise and may last several days (Pyne, 1994). During this phase blood vessels re-enter the damaged area of the muscle fibre, allowing access for white blood cells (Armstrong et al., 1991; Pyne, 1994; Sorichter et al., 1999). Phagocytic mononuclear cells, such as macrophages, play an important role in this stage of the injury process by invading the damaged muscle and removing the damaged proteins (Armstrong, 1990; Clarkson, 1997; Clarkson & Sayers, 1999). Delayed impairments in muscle function may provide evidence that phagocytic activity within an injured muscle may create further 'secondary' damage as contractile proteins are removed. Fluid also accumulates at the site and this results in the characteristic swelling observed after a bout of high-force eccentric exercise (Clarkson & Sayers, 1999).

Stress proteins (also called heat shock proteins) are synthesised in response to the reactive oxygen species, as well as increased muscle temperature and Ca^{2+} concentration, and function to remove damaged proteins (Clarkson & Sayers, 1999). HSP 70 is the most notable of the stress proteins involved in muscle damage (Clarkson & Sayers, 1999; Sorichter et al., 1999). HSP 70 is involved in the denaturation and degradation of proteins as well as protein synthesis (Clarkson & Sayers, 1999).

2.1.4 Regenerative Phase

Muscle tissue has remarkable powers of regeneration with evidence of this ability noticeable 4 to 5 days after the initial damage (Appell et al., 1992; Armstrong et al., 1991). As mentioned above, stress proteins may be involved in regeneration of muscle tissue as well as the degradative process (Clarkson & Sayers, 1999). Also, a subpopulation of macrophages, known as $ED2^{+}$ macrophages, has been reported in the muscle at the start of regeneration. It is therefore believed that these macrophages may somehow regulate the regeneration of muscle fibres (Clarkson & Sayers, 1999; Pyne, 1994; Sorichter et al., 1999).

The actual mechanisms that result in the activation of the regenerative process are not well understood and it is proposed that the mechanisms may be different for various muscle types (Schultz, 1989). Satellite cells from the uninjured areas of the muscle fibres are activated and migrate to the damaged area, where they mature into myoblasts. They then fuse and develop new myotubes and new fibres are formed to replace those that had been injured (Jones & Round, 1990, p. 173; Schultz, 1989).

Researchers have found that resistance training reduces muscle protein turnover after a bout of eccentric exercise and that the rate of protein synthesis may be greater in trained subjects compared to untrained subjects (Gibala et al., 2000; Phillips, Tipton, Ferrando, & Wolfe, 1999; Tesch, 1988). This has been implicated in a shorter time course for tissue repair in resistance-trained subjects than for untrained subjects after a damaging bout of exercise. Hence, a faster recovery in muscle functions was predicted for T subjects than for UT subjects over the period of this study.

2.1.5 Excitation-Contraction Uncoupling

Excitation-contraction (E-C) uncoupling is a poorly understood phenomenon, which has been observed after bouts of eccentric exercise. E-C coupling is the cascade of events starting with acetylcholine being released at the neuromuscular junction and ending with the release of Ca^{2+} ions from the sarcoplasmic reticulum (SR) (Warren, Ingalls, Lowe, & Armstrong, 2001). If eccentric exercise were to result in an impairment of the E-C pathway, then the affected fibres would not be able to be recruited to their full potential. Physical disruption to muscle fibres does not appear to completely account for the loss in ability to produce force after eccentric exercise. It has been proposed that E-C uncoupling can explain this disparity, accounting for up to 75% of the loss of force after an eccentric exercise bout (Warren et al., 2001).

2.2 Responses to Eccentric Exercise-Induced Muscle Damage

2.2.1 Maximal Voluntary Force

Maximal isometric torques have been shown to drop to as little as 40% of their pre-exercise levels at the end of an eccentric exercise bout (Clarkson, 1997; Clarkson et al., 1992; Nosaka, Clarkson, McGuiggin, & Byrne, 1991). The ability to produce maximal force usually returns to baseline levels by 10 to 12 days after the exercise bout, however, studies have shown that it can take even longer than this to regain full strength (Howell, Chleboun, & Conatser, 1993; Nosaka, Clarkson, & Apple, 1992; Pearce, Sacco, Byrnes, Thickbroom, & Mastaglia, 1998). This consequence of eccentric exercise would obviously have a large bearing on sporting performance yet most studies involve untrained subjects, not highly trained athletes. Hence, this particular study was implemented.

2.2.2 Range of Motion (ROM)

Eccentric exercise of the elbow flexors results in a reduced ROM at the elbow. The angle at which the arm hangs, relaxed by the side of the body decreases (the arm hangs in slight flexion) immediately after eccentric exercise and continues to decrease until the third day post-exercise (Clarkson et al., 1992; Nosaka et al., 1992). After this time it gradually returns to normal. This function is also affected at the other end of the range of motion and an inability to fully flex the forearm is seen immediately after exercise (Clarkson et al., 1992; Nosaka et al., 1991). It is believed that the accumulation of Ca^{2+} in the muscle fibres after they are damaged causes an involuntary contracture of the damaged muscle and this results in a reduced relaxed elbow angle (Clarkson et al., 1992). Either stretched sarcomeres or E-C uncoupling may be able to explain the inability to fully flex the elbow after a bout of damaging exercise to the elbow flexors, but as yet no conclusive evidence has been found in support of either theory (Clarkson et al., 1992).

2.2.3 Soreness and Tenderness (SOR)

Perhaps the most disconcerting response a person endures after participating in exercise that involves eccentric muscle actions is the soreness that develops in the muscles in the days following the exercise bout. The pain experienced usually peaks in intensity 2 or 3 days after the exercise bout and then fades away by day 7 post-exercise (Chleboun, Howell, Conaster, & Giesy, 1998; Clarkson et al., 1992; Howell et al., 1993; Nosaka et al., 1991). If the subject is fortunate then the worst of it may be over in about 24 hours (Clarkson, 1997; Fielding et al., 2000).

2.2.4 Circumference (CIR)

Swelling usually increases over the first couple of days after the exercise to a level at which it is maintained until about 5 days post-exercise (Chleboun et al., 1998). However, peak swelling, which is indicated by increases in arm circumference, may not occur until as late as 10 days after the damaging bout of exercise (Clarkson, 1997). It has even been suggested that the time course of swelling follows 2 phases with increases in swelling immediately after exercise, which subsides over 6 hours, only to increase again over the next 3 days (Howell et al., 1993).

2.2.5 Creatine Kinase (CK)

Because CK is a molecule that is too large to escape from muscle fibres unless the cell membrane is damaged, CK levels in the blood are often used to indicate that muscle damage has occurred after a bout of exercise (Evans, 1987). Generally, if a person has a high CK response to exercise then their damage related responses will also be large (Nosaka & Clarkson, 1996). However, the amount of CK found in the blood does not accurately indicate the amount of damage to a muscle (Sorichter et al., 1999). CK increases follow a similar time course to that of swelling, with a gradual increase in the first two days before a large rise to peak 4 or 5 days post-exercise (Chleboun et al., 1998; Pearce et al., 1998; Sayers, Clarkson, & Lee, 2000; Schwane, Buckley, Dipaolo, Atkinson, & Shepherd, 2000). Although CK is not an accurate measure of muscle damage, it is a quick and convenient method to establish the fact that damage has been induced by a bout of exercise (Sorichter et al., 1999).

2.3 Adaptive Responses to Eccentric Exercise

2.3.1 Changes in Muscle Responses after Repeated Bouts of Eccentric Exercise

It is established that performing a bout of eccentric exercise results in smaller changes in the indirect markers of muscle damage following a subsequent bout of eccentric exercise (Chen & Hsieh, 2000; Clarkson & Tremblay, 1988; Nosaka et al., 1991). The protective effect of an initial bout of eccentric exercise can last for up to 10 weeks (Paddon-Jones et al., 2000). Studies have shown that a second bout of eccentric exercise produces less soreness, less CK activity and less of a change in the relaxed arm angle (Foley et al., 1999; Nosaka et al., 1991). The decrease in ability to fully flex the arm and to produce maximal isometric force may be as severe after the second exercise bout as it was after the first, but these two muscle functions recover much more quickly after a second bout of eccentric exercise (Nosaka et al., 1991).

The fact that a bout of eccentric exercise does not have to produce large amounts of damage to induce a protective effect in subsequent bouts of eccentric exercise (Clarkson & Tremblay, 1988; McHugh, Connolly, Eston, & Gleim, 1999) may hint towards the results of this study. Resistance-training bouts often produce delayed muscle soreness and temporary losses in strength, which indicates that some damage to the muscles has occurred. Although normal training bouts are not as intense as the eccentric protocols often used in muscle damage studies, they are designed to overload the muscles so that adaptations will occur, which make the muscles more capable of handling heavy loads. This lead to belief that the trained subjects who participated in this study would show responses to the bout of eccentric exercise similar to those reported for repeated bouts of eccentric exercise and the attempt to either prove or disprove this belief.

2.3.2 Effect of Resistance Training

To the researchers knowledge, there has been a paucity of research into how resistance training effects the responses to eccentric exercise, which have already been well documented on untrained subjects. Gibala et al. (2000) used muscle biopsies to study the effects of eccentric exercise on strength-trained men and the results were compared to untrained subjects from a previous study. They concluded that approximately half as many fibres were disrupted for trained subjects as for untrained subjects and that the disruption suffered by the trained subjects was less severe than that suffered by the untrained subjects.

If trained subjects suffered less physical disruption to the tissues of eccentrically exercised muscles than untrained subjects, then it would seem reasonable to predict that the muscle functions of trained subjects would also show less of a decrement after high-intensity eccentric exercise. However, it appears that until now this prediction has not been examined through a specifically designed research study. If trained subjects prove to respond differently than untrained subjects do to a bout eccentric exercise, then the time courses of their muscle responses may give clues as to which stage of the damage process training produces protective adaptations.

Chapter 3

Methodology

3.1 Subjects

Following approval from Edith Cowan University's Human Research Ethics Committee, sixteen subjects were recruited to complete the study. Procedures for recruiting subjects included advertising on notice boards, word of mouth and approaching appropriate associates of the researchers. Table 3.1 outlines the characteristics of the subjects in each group. All subjects (males aged 18 to 45 years) were required to sign an informed consent form and complete a medical questionnaire (see appendix A) to ensure that they were free from any musculoskeletal or neuromuscular disorder or any injury to the elbow, shoulder or wrist of the arm that was to be exercised. Subjects were recruited based on their resistance-training history. All trained (T) subjects had participated in resistance training at a frequency of at least 3 times per week for a minimum of 3 years prior to commencement of the study, with each subject having included isolated arm exercises in their training program. Untrained (UT) subjects had not trained with weights for the 12 months prior to the study. A comparison of the torque-velocity relationship of each group before the commencement of the study showed no indication of a difference in muscle fibre type characteristics between the two groups (figure 3.1). All subjects were required to refrain from resistance training during the course of the study. One to three days prior to commencement of the study subjects were familiarised with the testing procedures and provided with a demonstration and verbal description of the eccentric exercise task that was to be completed.

Table 3.1

Trained and Untrained Subjects Physical Characteristics (mean ± SD)

	Trained	**Untrained**
	n=8	n=8
Age (yrs)	31 ± 8.8	27 ± 6.6
Height (cm)	173.7 ± 7.2	176.6 ± 5.7
Weight (kg)	77.0 ± 7.9	81.0 ± 19.3
Arm CIR (cm)	29.9 ± 2.5	28.3 ± 3.3

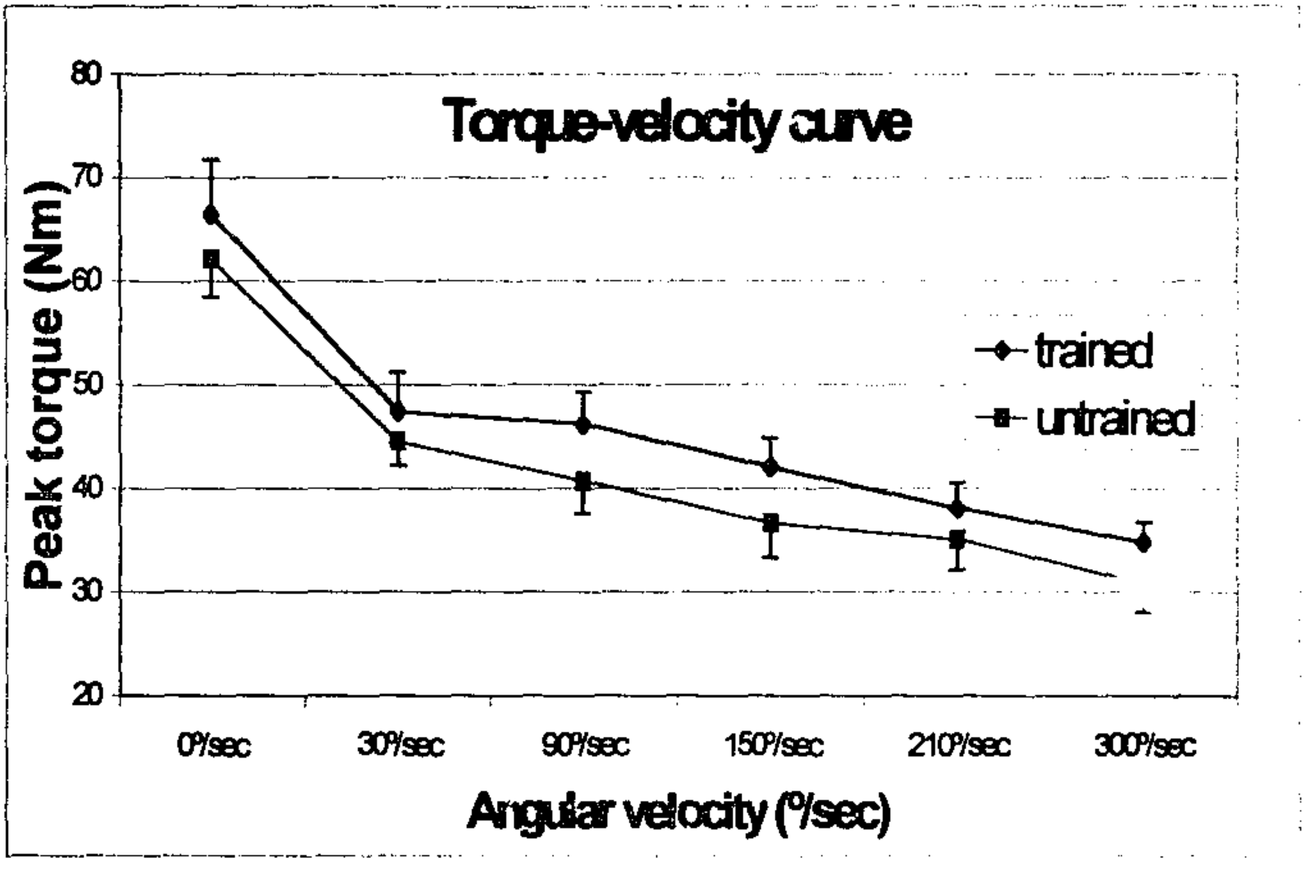

Figure 3.1 The torque-velocity relationships (mean ± SEM) of the T (n = 8) and

3.2 *Equipment*

Isokinetic dynamometer (Cybex 6000 – Ronkonkoma, NY)
Amlab 2 software program and IBM compatible desktop computer (Lewisham, Aust.)
Reflotron spectrophotometer (Boehringer-Mannheim – Pode, Czech Republic)
Creatine kinase assay strips (Boehringer-Mannheim – Pode, Czech Republic)
Capillary tubes and a pipette (Boehringer-Mannheim – Pode, Czech Republic)
Goniometer (Baseline)
Constant tension measuring tape (Lafayette Instrument – Lafayette, IN)
100mm visual analogue scale

3.3 *Timeline for Measures*

The dependant variables of isometric torque, dynamic torque, arm circumference and range of motion were recorded 1 to 3 days prior, immediately prior, immediately following, 30 minutes and 1, 2, 3, 4 and 5 days after the exercise bout, which is described in section 3.4. These variables were also measured 6 and 7 days post-exercise for UT subjects and that data used for the purposes of another study. Plasma CK concentration was not measured immediately after or 30 minutes after the exercise bout as no change to this variable was expected to occur over this short time period. Perceived levels of post-exercise soreness were recorded on days 1 to 5 for T and days 1 to 7 for UT subjects. Soreness was assumed to be 0 for all subjects prior to the exercise intervention.

3.3.1 Isometric Strength

Maximal voluntary isometric elbow flexor torque was measured at elbow angles of 90° and 150° (ie. half flexed and near extension) on a Cybex 6000 isokinetic dynamometer. The subject was seated with their arm supported at 45° of shoulder flexion on an arm curl (preacher curl) bench (figure 3.2). The elbow was aligned with the axis of rotation of the lever arm of the isokinetic dynamometer. Subjects were encouraged to perform two maximal contractions at each angle, holding the contraction for three seconds. Thirty seconds of rest was allowed between the two efforts at each specific angle and 60 seconds of rest was allowed during the transition between the two different angles. The torque readings during each contraction were delivered from the isokinetic dynamometer to a desktop computer with an Amlab 2 program. This program allowed the recording of torque throughout the duration of the contraction. The torque was displayed on a VDU screen as a trace and the data saved to the hard drive enabling it to be replayed and analysed at a later date. The peak torque produced during each contraction was determined by measuring the highest point recorded on the trace. The higher magnitude torque of the two contractions was used for analysis purposes. The torque recording system had been calibrated prior to testing by hanging known weights from the lever arm of the isokinetic dynamometer and adjusting the gains from the Amlab 2 amplifier so that the torque readings matched those that were calculated for the weight on the lever arm.

Figure 3.2 The set-up of a subject on the arm curl bench and Cybex 6000 isokinetic dynamometer. The subject's arm being tested was in the isometric 150° position at the time that this photograph was captured.

3.3.2 Dynamic Strength

The ability to produce torque at specific speeds of elbow flexion was determined using angular velocities of 30°, 90°, 150°, 210° and 300° per second. Subjects performed two maximal voluntary contractions at each velocity with no rest in between each attempt and 1 minute rest between velocities. The arm moved through a 90° range of concentric motion, beginning at full extension. The peak of each contraction was measured and the higher of the two peaks at each speed was used in the analysis of results.

3.3.3 Soreness and Tenderness (SOR)

Muscle soreness was reported using a visual analogue scale while the arm was forcibly flexed and extended in a standard manner by the investigator. The subject was instructed to place a mark on a 100mm line for both the flexion and extension movement soreness ratings. Subjects were told that 0mm indicated no pain and 100 indicated "unbearable" pain. Muscle tenderness (which is considered as soreness upon palpation for the purposes of this study) of the upper arm and the forearm was reported using the same visual analogue scale. The upper arm was palpated in three areas by the investigator and the average of these scores taken as a measure of upper arm tenderness. The brachioradialis was also palpated to determine the tenderness of the forearm. Appendix B is an unused copy of the muscle soreness assessment sheets used in this study.

3.3.4 Arm Circumference (CIR)

Circumference of the upper arm was measured using a constant tension tape (Lafayette Instrument) while the arm was relaxed and hanging by the subjects' side. Sites at 3, 5, 7, 9 and 11cm above the crease line of the elbow used for measurement purposes and the average of the 5 measurements was recorded as the arm circumference.

Landmarks used in locating the points for the circumference and range of motion (see below) measurements were marked on the skin with semi-permanent marker ink and the subjects were instructed not to remove them until the data collection was finished. This aided in reliability as the measurements were taken from identical locations during each testing session.

3.3.5 Range of Motion (ROM)

ROM measurements at the elbow were obtained using a plastic goniometer (Baseline). All elbow angle measurements were determined while the subject was in a standing position. Flexed arm angle (FANG) was determined as the elbow angle resulting when the subject fully flexed their elbow joint with their hand in a neutral position, keeping their elbow at their side. Relaxed arm angles (RANG) were measured when the subjects let their arm hang at their side with the forearm in a neutral position.

3.3.6 Plasma Creatine Kinase (CK) Concentration

Capillary tubes were used to collect approximately 30μl of whole blood from a fingertip puncture made by a spring-loaded lancet. The sample was immediately pipetted onto a CK test strip and analysed in a Reflotron spectrophotometer (Boehringer-Mannheim). If the CK concentration of the sample was too large for the spectrophotometer to analyse then a new sample was diluted in 0.9% saline solution.

3.4 Reliability of Measurements

In order to establish a measure of reliability coefficients of variation (V) were calculated for maximal isometric torque fixed elbow joint angles of 90° and 150°, CIR, RANG and FANG using the data gathered from the familiarisation session and the pre-exercise test results of 12 subjects from both groups. The resulting 'V' values were 5.73%, 6.26%, 1.0%, 1.45% and 8.8% respectively.

3.5 Exercise Protocol

Each subject performed a bout of eccentric exercise that was designed to work the elbow flexor muscles. The preacher bench and isokinetic dynamometer set-up was identical to that employed during the isometric strength assessment. The arm that was to be exercised was assigned to each subject ensuring that there was a balance between dominant and non-dominant arms.

The subjects performed 10 sets of 6 repetitions of maximal voluntary isokinetic eccentric contractions of the elbow flexor muscles at a speed of 90° per second. They were continually encouraged to apply maximal resistance against the lever arm of the isokinetic dynamometer during each repetition. The range of motion was restricted to 90° commencing from a half-flexed position (approximately 90° at the elbow) and terminating at a fully extended position (0° of flexion or approximately 180° at the elbow). Subjects were provided 10 seconds of passive rest between each repetition as the lever arm was returned to the starting position (elbow half flexed) and 180 seconds of rest between each set of exercise.

3.6 Analysis of Results

Changes in the criterion measures (dependent variables) over time were analysed by applying a one-way repeated measures ANOVA to each group. Each criterion measure was analysed separately. Simple contrasts anchored to the first data point (pre exercise measurements) were used to determine which points were significantly different to the first data point. Repeated contrasts were employed to detect any significant changes from one testing session to another. Statistical significance was set at $p<0.05$ for these analyses.

Planned comparisons at days 1, 3 and 5 days post-exercise were employed to test for any significant differences between the two groups. Independent T-tests were chosen for the comparisons and applied to each criterion measure, with the exception of plasma CK concentration, which included a T-test for the pre-exercise values. The

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Planned comparisons at days 1, 3 and 5 days post-exercise were employed to test for any significant differences between the two groups. Independent T-tests were chosen for the comparisons and applied to each criterion measure, with the exception of plasma CK concentration, which included a T-test for the pre-exercise values. The difference between the groups' responses in plasma CK concentration was determined using absolute values. ROM differences between T and UT subjects were calculated on change from pre-exercise values in degrees. The differences for the responses of the other variables were calculated using relative measurements. These measurements were expressed as a percentage of the pre-exercise recording for each subject as appropriate. As T subjects were expected to show less of a response to the potentially damaging bout of eccentric exercise for all of the criterion measures, the T-tests were one-tailed and a Bonferroni correction factor was used to adjust the alpha significance level in accordance with the number of T-tests conducted.

3.7 Limitations and Delimitations

3.7.1 Limitations

Limitations of this study related to the subjects' perceptions of the tasks that were completed throughout their participation in the study. Maximal voluntary torques were not verified as being maximal through the use of twitch interpolation and therefore may have been influenced by motivational factors. However, it was attempted to provide each subject with similar verbal motivation throughout their testing and exercise sessions. Also the rating of soreness used is a subjective measure and is dependent on the subjects' pain threshold and other psychological factors at the time of testing. Other limitations related to the truthful and accurate answering of the questionnaires provided for the purposes of this study.

Chapter 4

Results

4.1 Isometric Strength

An independent samples T-test on the absolute data showed no significant difference between maximal voluntary isometric torque of the two groups prior to the exercise intervention. Maximal voluntary isometric torques at 90° of elbow flexion ranged from 45.5 to 77.9Nm (62.14 ± 10.3Nm, mean ± SD) for UT, and 43.3 to 86.3Nm (66.48 ± 14.8Nm, mean ± SD) for T subjects. Similarly, there was no significant difference between the groups at an elbow angle of 150° (UT = 43.13 ± 13.2Nm; T = 49.6 ± 10.1Nm).

Immediately following the exercise bout, T subjects' maximal voluntary torque at 90° of elbow flexion declined to approximately 73% of their pre-exercise level. In comparison, UT subjects experienced an even greater degree of force loss, dropping almost 45% from their pre-exercise recordings (figure 4.1). Both groups displayed protracted force decrements, remaining significantly weaker 3 days following the exercise bout. However, as hypothesised, the T group recovered more rapidly than the UT group. At days 1 and 3 post exercise T subjects had recovered significantly more ($p<0.05$) peak isometric 90° torque than UT subjects. Three days after the exercise bout T subjects' peak isometric 90° torque had recovered to almost 90% of pre-exercise values, whereas UT subjects displayed almost no recovery at this time. On the 4th day post-exercise T subjects recorded peak isometric torques averaging approximately 93%. Seven days following eccentric exercise the peak isometric torque of the UT group was still 20% lower than that prior to the exercise bout.

Peak isometric torque at 150° of elbow extension displayed an almost identical response as detailed above for the isometric 90° torque (figure 4.2). Both groups experienced significant ($p<0.05$) decreases in torque production at this angle until the 4th day post-exercise. However, unlike the finding for isometric torque at 90° of flexion, at no time was there a significant difference between the two groups' strength at 150° of elbow extension.

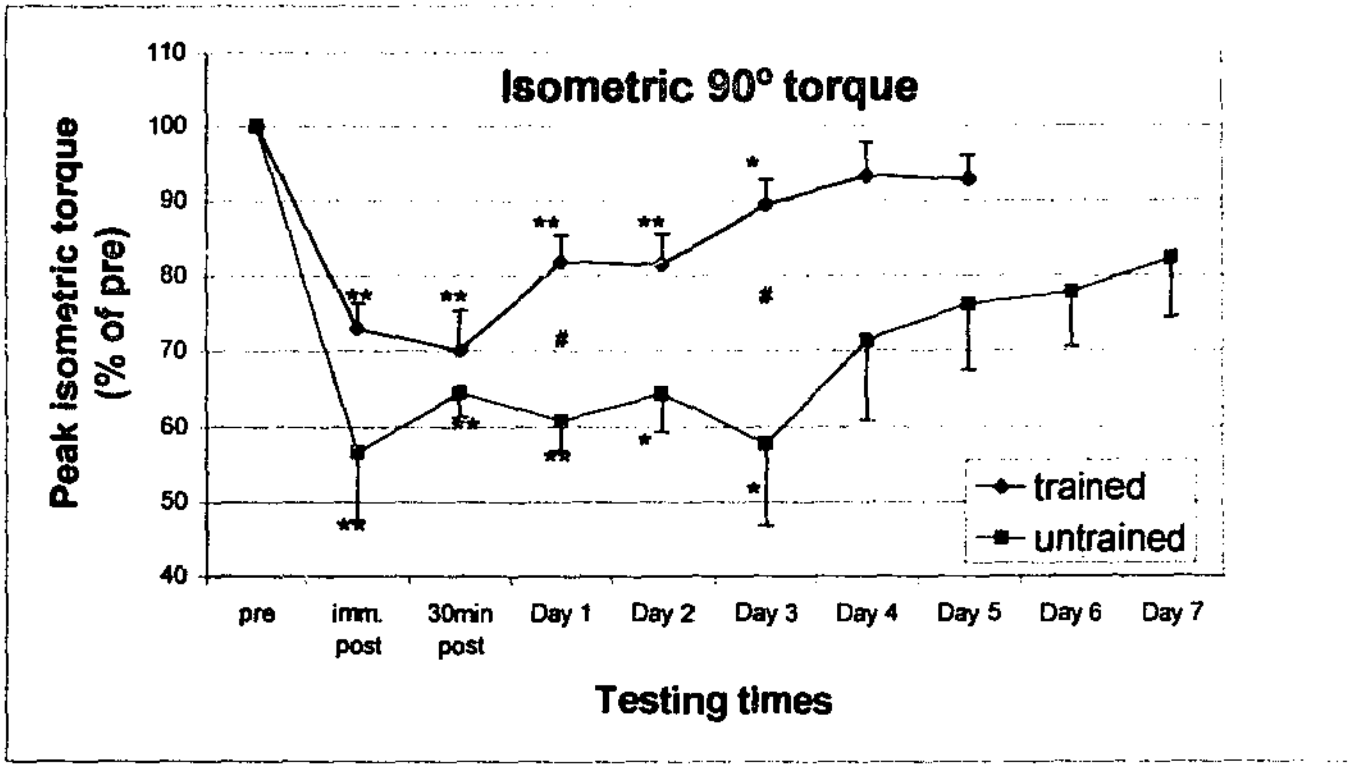

Figure 4.1 Normalised maximum voluntary isometric torque at 90° (mean ± SEM) of elbow flexion, expressed as % of pre-exercise, for T (n = 8) and UT (n = 8) groups. * represents a significant ($p<0.05$) and ** represents a highly significant ($p<0.01$) difference from pre-exercise, # represents a significant ($p<0.033$) difference between groups.

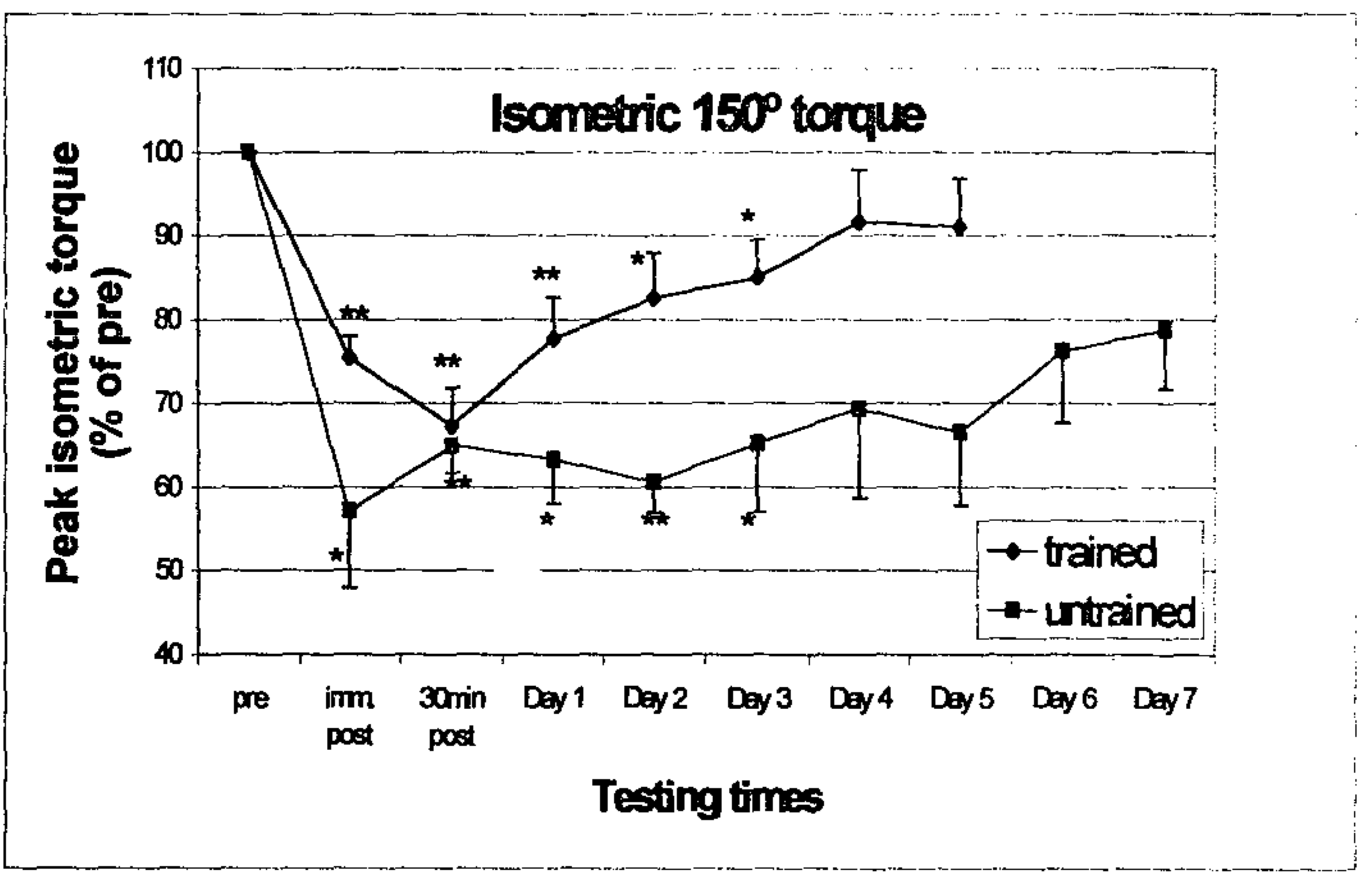

Figure 4.2 Normalised maximum voluntary isometric torque at 150° (mean ± SEM) of elbow extension, expressed as % of pre-exercise, for T (n = 8) and UT (n = 8) groups. * represents a significant ($p<0.05$) and ** represents a highly significant ($p<0.01$) difference from pre-exercise.

4.2 Dynamic Strength

Both groups displayed similar decrements and recoveries in the maximal voluntary torque produced at different angular velocities as they did under isometric conditions. Figures 4.3, 4.4 and 4.5 are graphical representations of peak torques generated at angular velocities of 30°/second, 150°/second and 300°/second respectively. At each of these velocities both groups showed significant ($p<0.05$) decreases in maximal torque produced immediately after and 30 minutes after the eccentric exercise protocol.

Interestingly, the UT group's strength appeared to recover more quickly at higher velocities (figures 4.3, 4.4 and 4.5) compared to the slower velocities. At 30°/second, UT subjects' peak torques remained significantly reduced by 25% ($p<0.05$) on the last day of testing. In contrast, the last day that this group showed a significant ($p<0.05$) difference from pre levels of 300°/second torque was day 3 post-exercise. The strength at this velocity of testing had recovered to non-significantly different levels, greater than 85% of pre-exercise levels, by day 6.

In comparison to the UT group, the T group showed greater recovery in strength (figures 4.3, 4.4 and 4.5). By the end of the testing for this group their peak torques were close to, and in many cases exceeding, the pre-exercise measures. This was a result observed at each of the velocities tested. The greatest discrepancies between the two groups' levels of recovery were observed at the slowest angular velocity, where significant ($p<0.033$) differences occurred 1 and 3 days after the eccentric exercise.

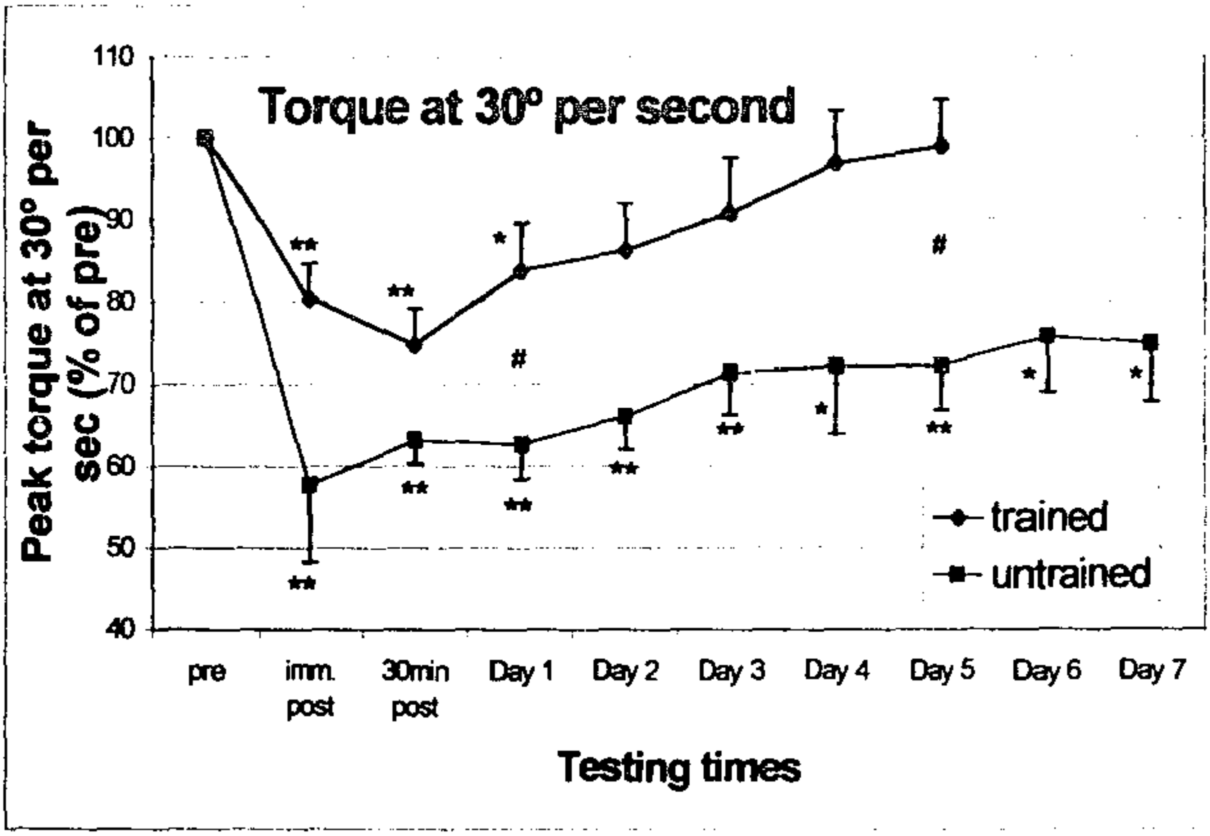

Figure 4.3 Normalised maximum voluntary torque at 30°/second (mean ± SEM), expressed as % of pre-exercise, for T (n = 8) and UT (n = 8) groups. * represents a significant ($p<0.05$) and ** represents a highly significant ($p<0.01$) difference from pre-exercise, # represents a significant ($p<0.033$) difference between groups.

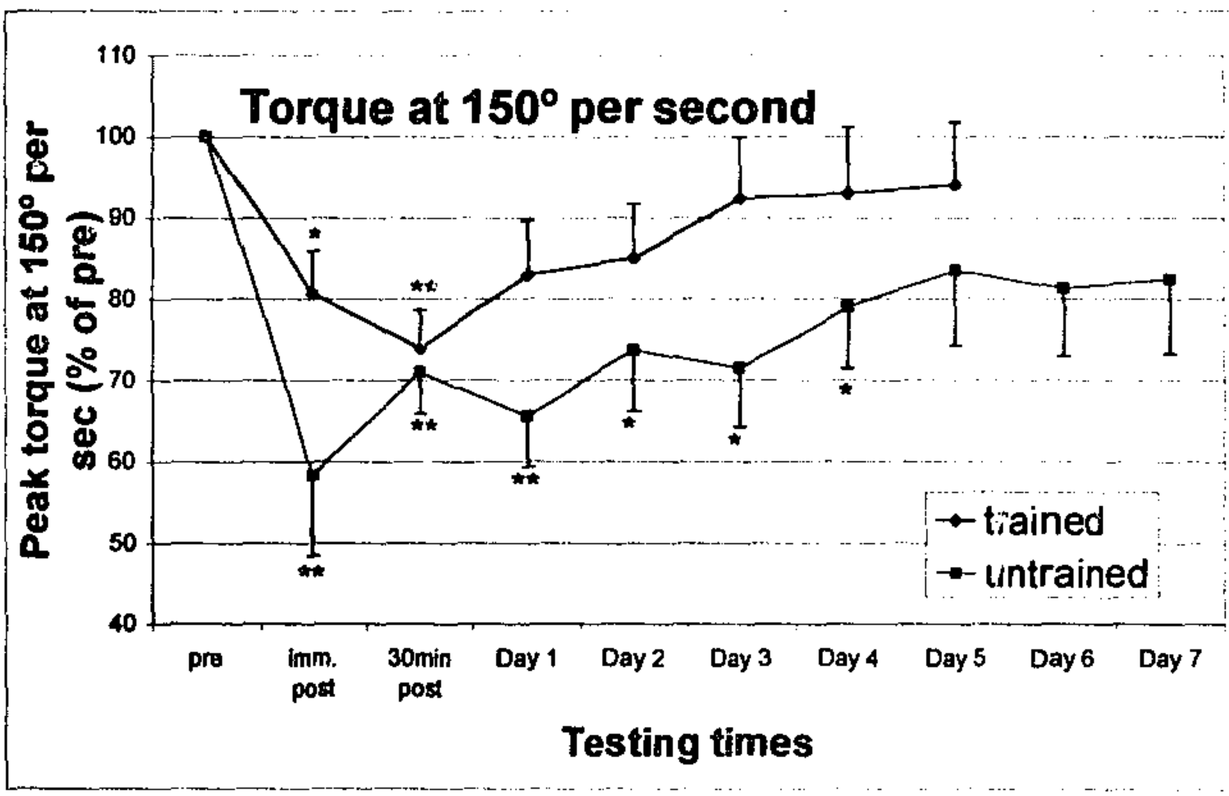

Figure 4.4 Normalised maximum voluntary torque at 150°/second (mean ± SEM), expressed as % of pre-exercise, for T (n = 8) and UT (n = 8) groups. * represents a significant ($p<0.05$) and ** represents a highly significant ($p<0.01$) difference from pre-exercise.

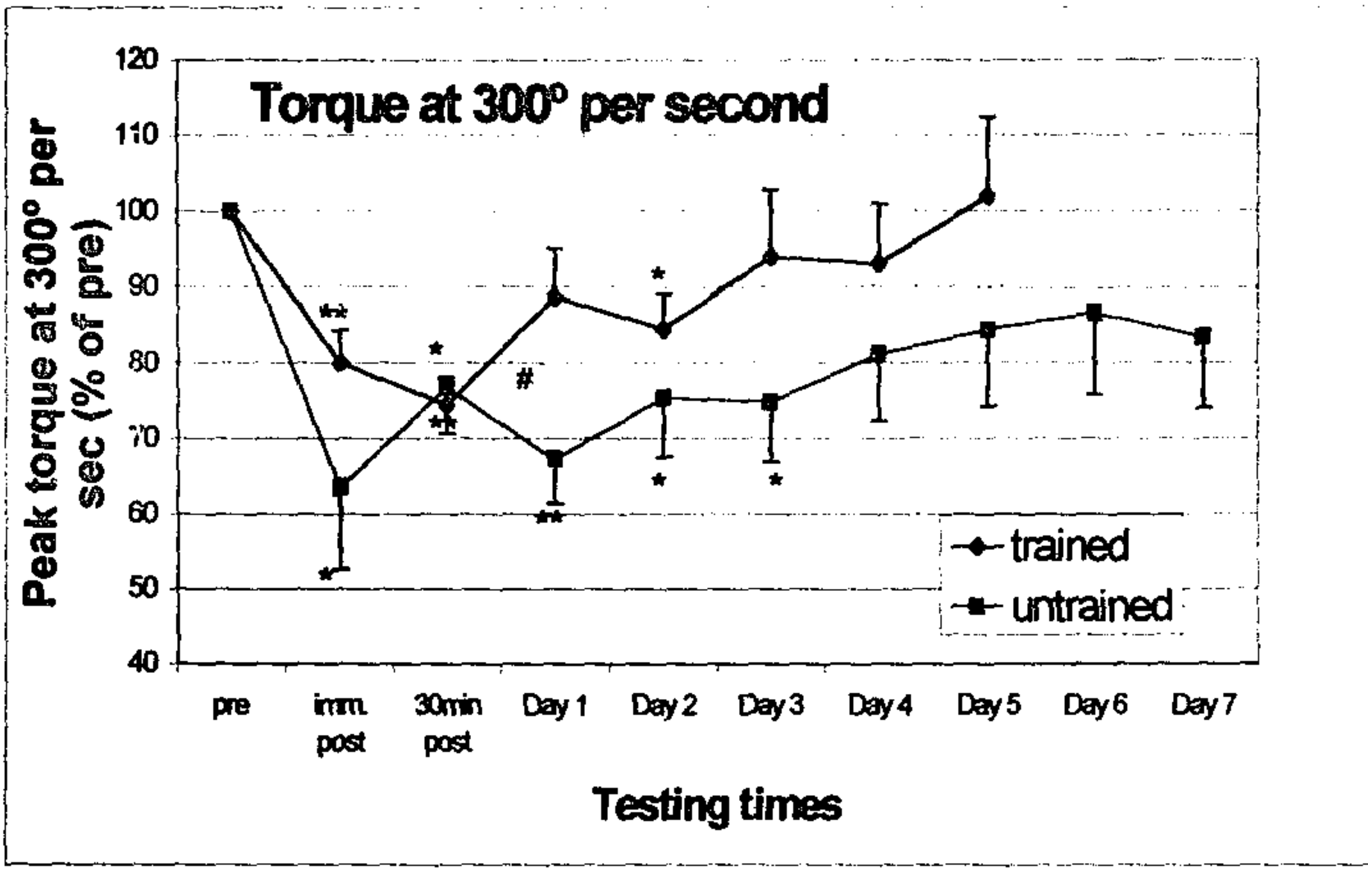

Figure 4.5 Normalised maximum voluntary torque at 300°/second (mean ± SEM), expressed as % of pre-exercise, for T (n = 8) and UT (n = 8) groups. * represents a significant ($p<0.05$) and ** represents a highly significant ($p<0.01$) difference from pre-exercise, # represents a significant ($p<0.033$) difference between groups.

4.3 Soreness and Tenderness (SOR)

It was hypothesised that T subjects would report less soreness and tenderness than UT subjects. However, analysis of the results concluded that this was not the case. One noteworthy finding from the recording of the SOR measures was that the peak SOR reported for T subjects occurred earlier than for UT subjects (figures 4.6, 4.7, 4.8 and 4.9). UT subjects displayed a time course for soreness more consistent with that found in previously published literature. SOR peaked around 2 to 3 days post-exercise for UT subjects, whereas T subjects generally rated the 1st day after the exercise as the most painful.

Figures 4.6 and 4.7 show how soreness for UT subjects lasted longer than for T subjects when passive extension and flexion movements were performed on the exercised arm. Although statistical analysis found more significantly ($p<0.05$) high levels of flexion SOR for T subjects than for UT subjects, average flexion SOR was higher for UT subjects at each day after the exercise. The small variability in the T group is likely to be the reason for these statistical findings

T subjects reported significantly ($p<0.05$) increased tenderness of both the forearm and upper arm over the first 3 days post-exercise (figures 4.8 and 4.9). T subjects were again significantly ($p<0.05$) tender upon palpation of the upper arm 5 days after exercise, even though the average upper arm SOR had decreased from the previous day's testing. Significant ($p<0.05$) levels of tenderness were reported by UT subjects up to 4 and 5 days after the exercise for forearm and upper arm respectively. The time course of upper arm SOR for the 2 groups appeared to parallel each other, with T subjects peaking earlier and recovering more quickly. Interestingly, peak forearm SOR was higher for T (34.9 ± 23.9mm) than for UT (25.3 ± 16.7mm) subjects. However, UT subjects suffered sustained tenderness in this area whereas T subjects recovered quickly.

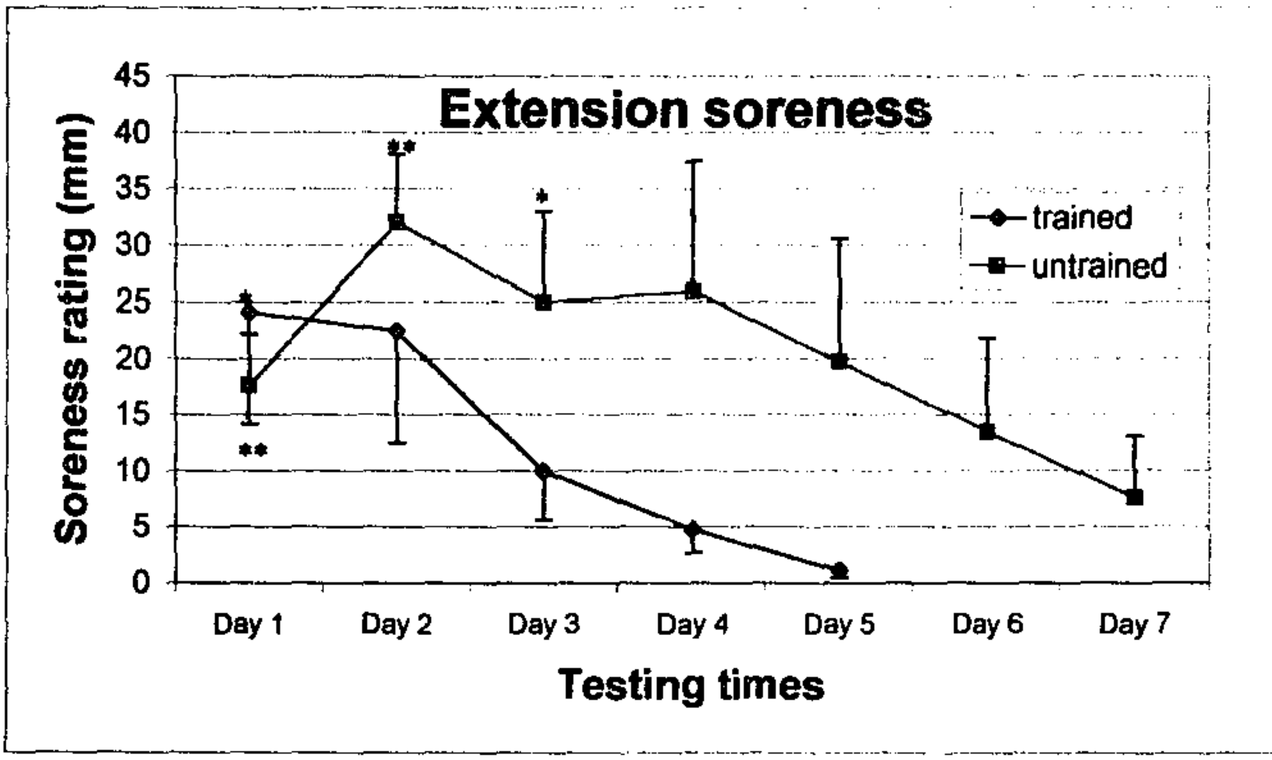

Figure 4.6 Soreness upon extension of the elbow (mean ± SEM) for T (n = 8) and UT (n = 8) groups. * represents a significant ($p<0.05$) difference from pre-exercise, ** represents a highly significant ($p<0.01$) difference from pre-exercise.

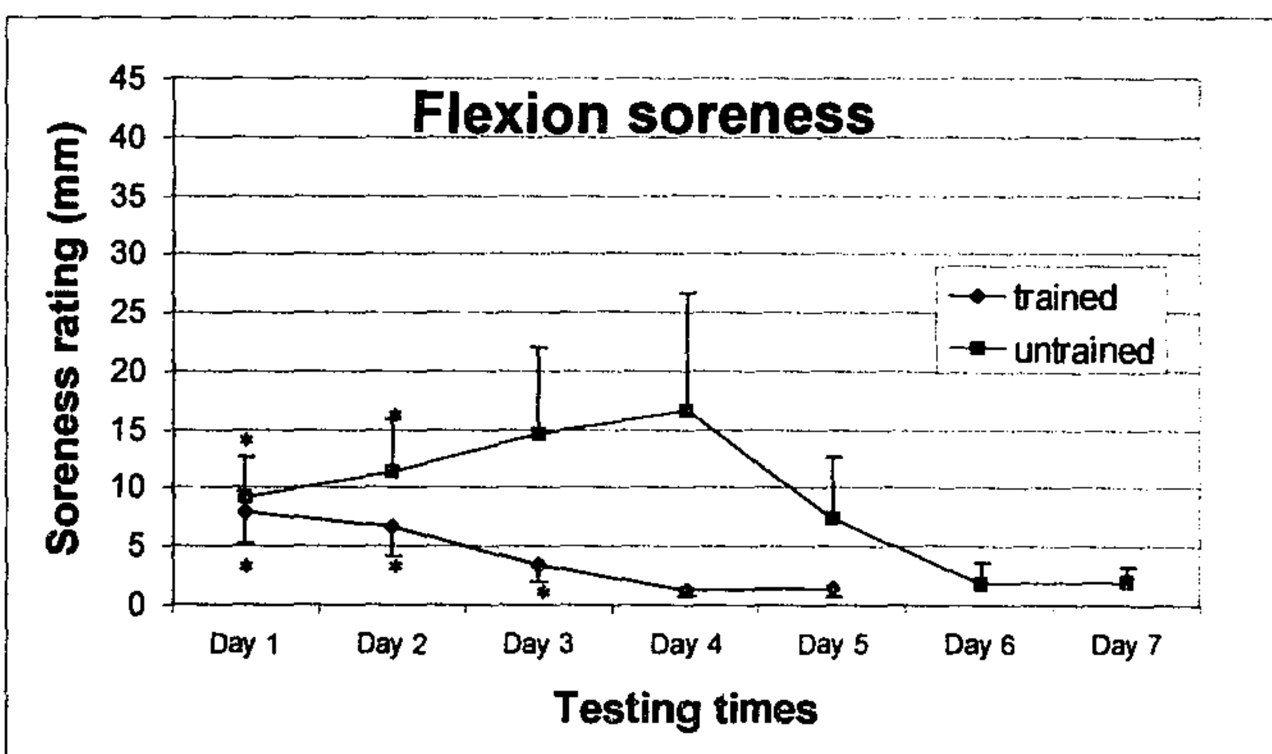

Figure 4.6 Soreness upon flexion of the elbow (mean ± SEM) for T (n = 8) and UT (n = 8) groups. * represents a significant ($p<0.05$) difference from pre-exercise.

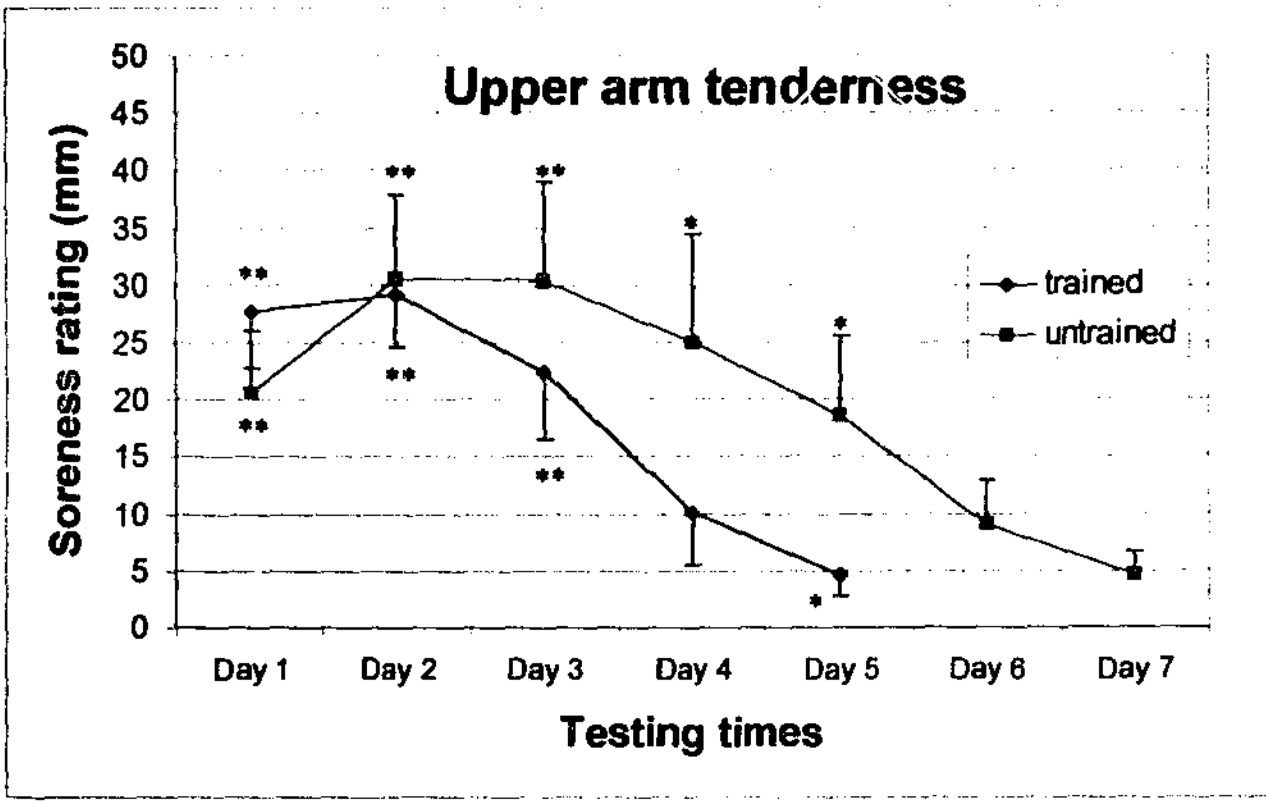

Figure 4.8 Upper arm tenderness (mean ± SEM) for T (n = 8) and UT (n = 8) groups. * represents a significant ($p<0.05$) difference from pre-exercise, ** represents a highly significant ($p<0.01$) difference from pre-exercise.

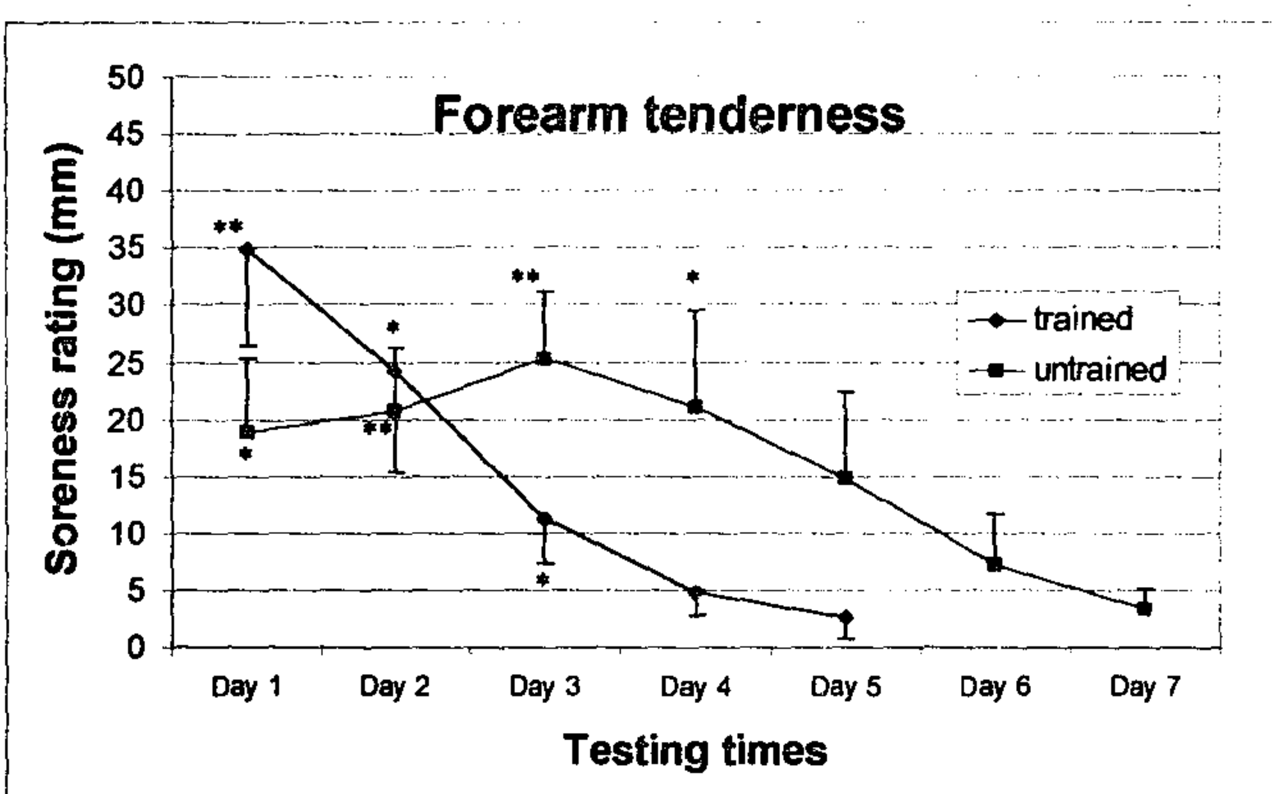

Figure 4.9 Forearm tenderness (mean ± SEM) for T (n = 8) and UT (n = 8) groups. * represents a significant ($p<0.05$) difference from pre-exercise, ** represents a highly significant ($p<0.01$) difference from pre-exercise.

4.4 Circumference (CIR)

Figure 4.10 represents the increase in CIR of both groups following the eccentric exercise bout. The peak increase in circumference in the T group (0.54 ± 0.47cm) occurred 1 day post-exercise. This was the only testing time at which this group displayed a significantly ($p<0.05$) increased CIR. In contrast, the CIR of UT subjects was significantly increased over the entire post-exercise recording period. Peak swelling for UT subjects (1.4 ± 1.2cm) occurred 5 days after the exercise bout.

Differences in change in CIR between the groups proved significant ($p<0.033$) only at 3 days post-exercise. It was at this time that the UT group showed a further, delayed increase in CIR while CIR of T subjects was continuing its return to pre-exercise levels.

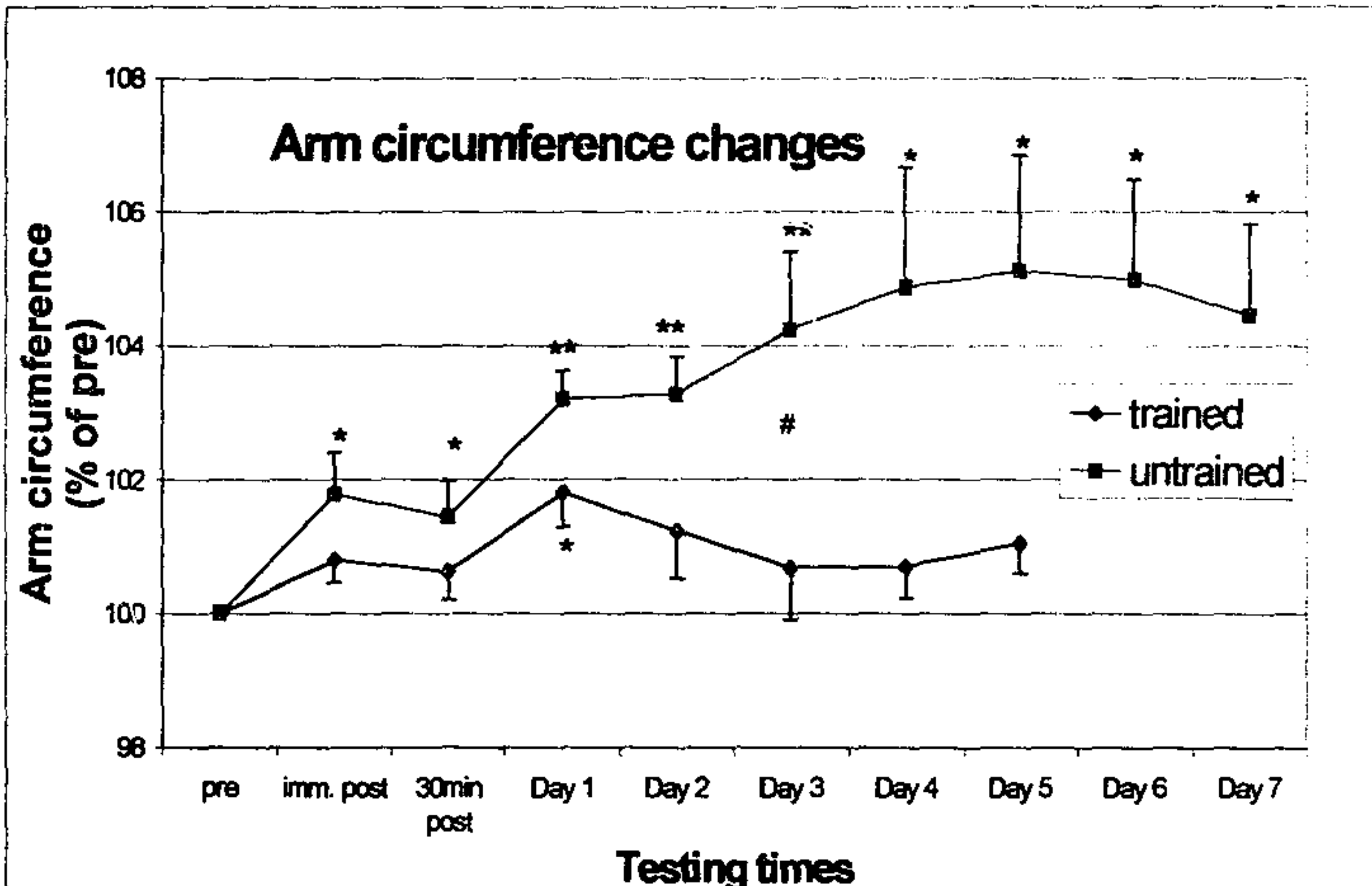

Figure 4.10 Normalised change in arm circumference (mean ± SEM), expressed as % of pre-exercise, for T (n = 8) and UT (n = 8) groups. * represents a significant ($p<0.05$) and ** represents a highly significant ($p<0.01$) difference from pre-exercise, # represents a significant ($p<0.033$) difference between groups.

4.5 Range of Motion (ROM)

4.5.1 Relaxed Elbow Angle (RANG)

The exercise bout resulted in a significantly ($p<0.05$) reduced RANG for both groups 1 day after (figure 4.11). Reduced RANG meant that when the arm was hanging loosely by the side of the subject the elbow was in a more flexed position than what it was prior to the exercise bout. RANG was still reduced ($p<0.05$) on the second day for the UT group. At no time was there a significant difference between the changes in RANG of the two groups. However, there was a delayed decrease in RANG on the 3rd day post-exercise for the UT group, which coincided with the delayed increase in CIR mentioned in the previous section.

4.5.2 Flexed Elbow Angle (FANG)

Figure 4.12 is a graphical representation of the ability of the subjects to flex the arm at the elbow over the days following the exercise intervention. The figure clearly shows a similar response by both groups of subjects immediately after and 30 minutes post-eccentric exercise. However, from this point on the T group displayed a much faster return to baseline. FANG remains significantly ($p<0.05$) increased in T subjects until 3 days post exercise, while significantly ($p<0.05$) larger angles are seen in the UT subjects every day except their last testing day. While both groups improved significantly ($p<0.05$) in their abilities to flex the elbow between the immediately post and 30 minute post testing times, only the T subjects display a further significant ($p<0.05$) improvement prior to testing on the 1st day post exercise. On the 3rd day after the exercise bout there is a significant ($p<0.033$) difference between the changes in FANG of each group.

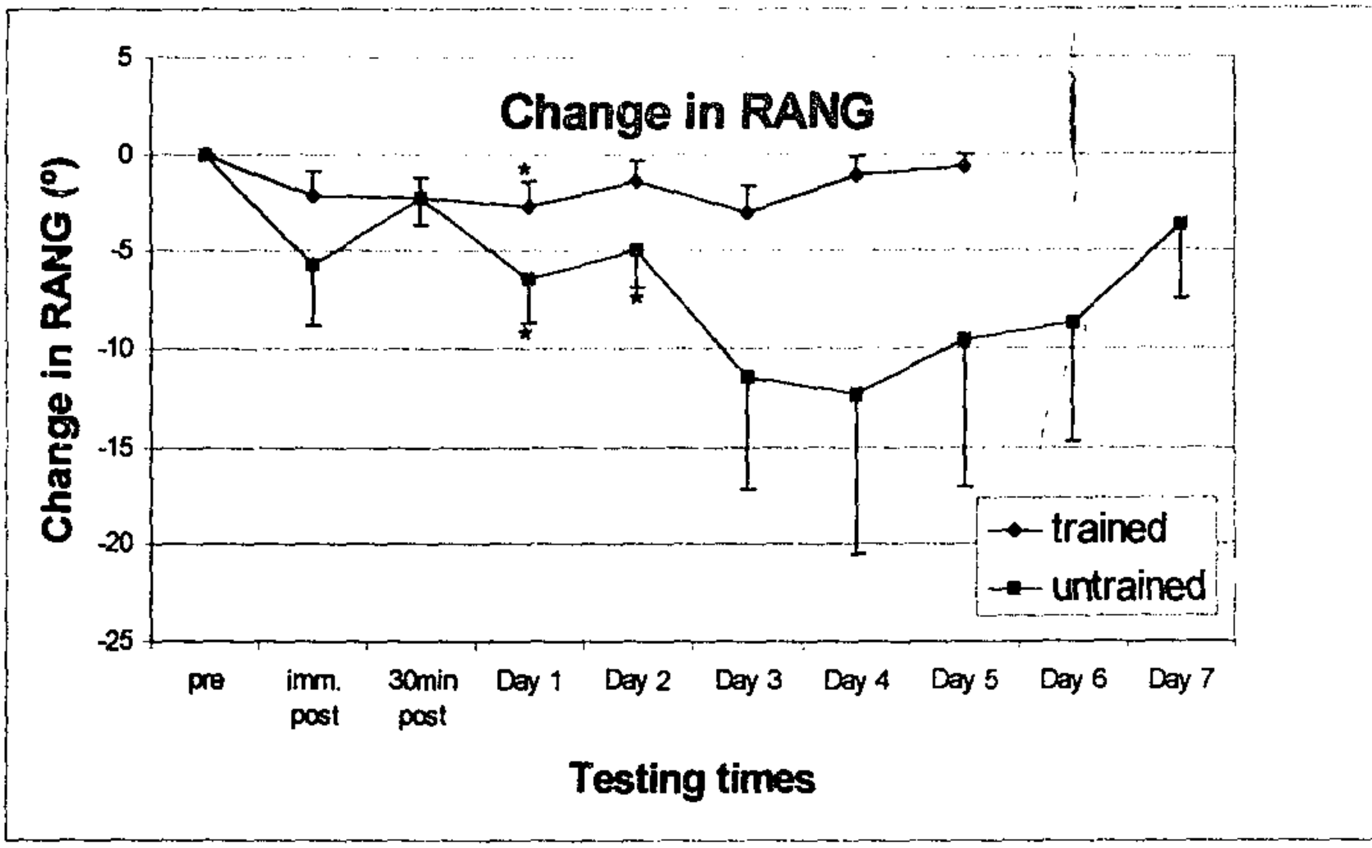

Figure 4.11 Change in RANG (mean ± SEM), expressed as degrees from pre-exercise, for T (n = 8) and UT (n = 8) groups. * represents a significant ($p<0.05$) difference from pre-exercise.

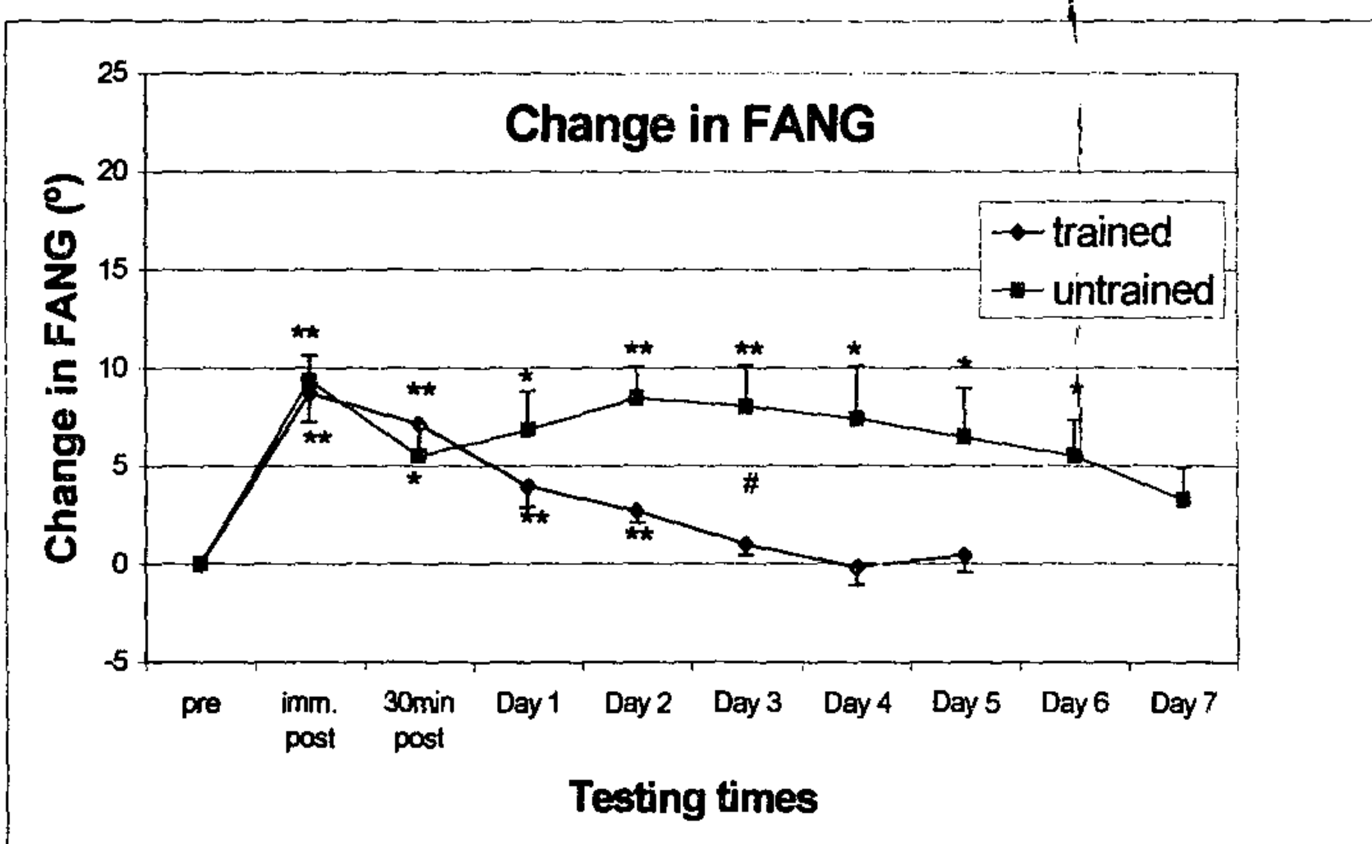

Figure 4.12 Change in FANG (mean ± SEM), expressed as degrees from pre-exercise, for T (n = 8) and UT (n = 8) groups. * represents a significant ($p<0.05$) and ** represents a highly significant ($p<0.01$) difference from pre-exercise, # represents a significant ($p<0.033$) difference between groups.

4.6 Plasma Creatine Kinase (CK) Concentration

Figure 4.13 shows a much larger increase in the plasma CK concentration of UT subjects than in T subjects following the exercise bout. Peak CK concentrations averaged almost 3,000IU for UT subjects, with some readings in excess of 10,000IU. T subjects recorded their peak CK concentrations at the same testing time. However, the peak values for T subjects only averaged 750IU. The large variability in individual's responses (SD = 3,905IU for UT and SD = 973IU for T) meant that significant differences between the groups were not found. There was also no statistically significant difference in CK concentration over time for each group.

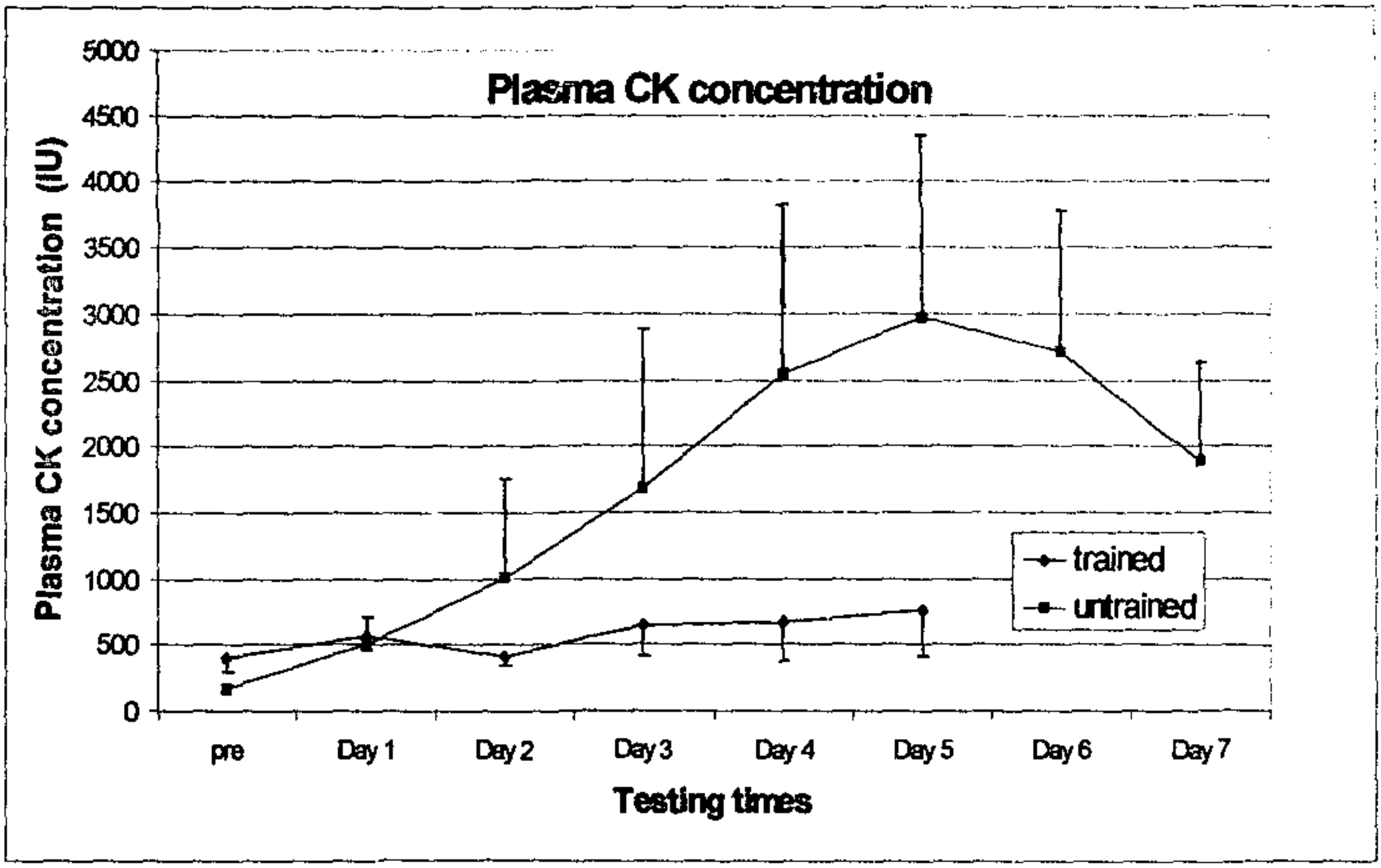

Figure 4.13 Change in plasma CK concentration (mean ± SEM), expressed as absolute values in IU, for T (n = 8) and UT (n = 8) groups.

Chapter 5

Discussion

There is a sparse amount of data gathered on the effect of eccentric exercise on subjects with a solid history of resistance-training. Some such data has been collected using an exercise protocol similar to the one used in this study (Gibala et al., 2000). However, there are some important differences between that study and this one. The intensity of the damaging bout of exercise in the study by Gibala et al. (2000) must be taken into consideration. Subjects performed 8 sets of 8 eccentric contractions of the elbow flexor muscles of one arm, using a dumbbell equal to 80% of their concentric 1-repetition maximum. Also, the volume of the bout of exercise used to elicit damage was less than the volume of the subjects' normal biceps training bouts. In comparison, the study completed for the purposes of this thesis uses a similar volume of contractions in the exercise protocol (10 sets of 6 repetitions) but these contractions are performed at maximal intensity on an isokinetic dynamometer. This means that maximum force can be generated throughout the entire range of movement, which is not the case for the use of dumbbells, thus creating a greater overload on the muscle. Gibala et al. (2000) focussed on quantifying the number of fibres damaged and the severity of the damage to each fibre after the exercise protocol. By reporting on the influence of training on aspects of muscle function after exercise induced muscle damage, rather than quantifying the damage produced by examining muscle biopsies, the results of this study should compliment the work of Gibala et al. (2000) and add to the body of literature on training and exercise-induced muscle damage.

5.1 Recovery of Strength

As predicted in hypothesis 1, T subjects' strength recovered earlier than UT subjects', furthermore there was a trend for the T group to experience less of a decline in peak torque immediately following the exercise bout, when compared to the UT group.

Probably the most crucial differences in the trends of recovery between the 2 groups occurred over the first 24 hours post-exercise. As the results showed, T subjects continued to decline in strength from immediately post to 30 minutes post-exercise but then began to recover by the next day. In contrast, UT subjects partially recovered over the 30 minutes after the exercise bout but then declined in strength again over the next 24 hours.

Repeated bouts of eccentric exercise in untrained subjects are characterised by similar decrements in maximal torque immediately after exercise, however, recovery has been shown to be more rapid following subsequent exercise bouts (Clarkson & Tremblay, 1988; Nosaka & Clarkson, 1995; Nosaka et al., 1991). T subjects in this study displayed a greater resistance to the immediate strength loss than untrained subjects performing repeated bouts of eccentric exercise. The most obvious explanation for this observation would be that resistance-training causes an adaptive response which results in less initial physical disruption to myofibres after a bout of high-intensity exercise. Nosaka and Clarkson (1995) suggested that a familiarisation with eccentric muscle actions would result in an ability to distribute the workload of an eccentric contraction more evenly amongst the fibres. Other researchers have hypothesised that training may result in the longitudinal addition of sarcomeres in muscle fibres (McHugh et al., 1999; Morgan & Allen, 1999). Both of these suggestions could explain less sarcomere "popping" and therefore retention in the ability to produce force. It may also be that T subjects are less susceptible to metabolic fatigue than UT subjects, however this is unlikely since after 30 minutes of rest the strength levels of UT and T groups were similar. T subjects actually suffered further decreases in maximal voluntary torque over the first 30-minute recovery period, indicating that metabolic fatigue was not the major factor determining the significant strength loss immediately post-exercise.

At 30 minutes post-exercise, both groups showed near identical force deficits, resulting from some recovery in the UT group and further decline in the T group (figures 4.1 and 4.2). A possible explanation for this finding is that impairment of excitation-contraction (E-C) coupling may account for some force loss in the early stages of exercise-induced muscle damage (Warren et al., 2001). They proposed that E-C uncoupling accounts for up to 75% of the force loss in the first few days of recovery. It may be that training provides minimal or no protection against the effects or causes of E-C uncoupling. The rapid recovery in strength for T subjects may indicate that their maximal voluntary toque losses were mainly due to E-C uncoupling and as this effect diminished there remained little physical disruption to the muscle fibres to prolong strength decrements.

Several days following the exercise bout a greater proportion of force loss is likely to be due to loss in contractile proteins as the damage progresses through the phagocytic phase (Warren et al., 2001). UT subjects showed a loss in peak torque similar to that reported in previous work (Clarkson et al., 1992; Nosaka et al., 1991), with little or no recovery in peak torque over the first few days. Evidence of a delayed, secondary injury due to phagocytic activity in the injured areas of the muscle is conveyed through the time courses of a variety of muscle responses after an injurious bout of exercise. This secondary damage can occur between 1 and 5 days after the exercise bout (Faulkner, Brooks, & Opitek, 1993) and the decrease in maximal voluntary torque between the 30 minutes post and 1 day post-exercise tests for UT subjects is consistent with this idea. In comparison, T subjects regained considerable strength 1 day after the exercise bout. This may indicate that they did not suffer as much secondary damage to the muscle as a result of phagocytic activity. This could be a consequence of less physical disruption to the sarcomeres, as postulated above, which would lead to the passive structures of the muscle having to endure less stress compared to UT subjects. Therefore, if the sarcolemma remained intact then there would have been no loss of Ca^{2+} homeostasis and the consequent initiation of degradative pathways would not have occurred. The accelerated recovery seen only 1 day post-exercise for t subjects may also indicate that they have an enhanced ability to repair the mechanisms that cause E-C uncoupling.

It has been reported that long-term resistance training leads to an increase in the rate of synthesis of proteins (Tesch, 1988). This could result in faster muscle regeneration, including E-C coupling machinery, in T subjects than in UT subjects and may also account, at least in part, for faster recovery observed in T subjects. However, the results of this current study do not make it possible to reach any definite conclusions as to the mechanisms behind T subjects' enhanced recovery against damage elicited by eccentric exercise.

5.2 *Soreness and Tenderness (SOR)*

The hypothesis that T subjects would report less SOR than their UT counterparts would was not supported by the findings of this study. Although there was no difference between the levels of SOR reported by the 2 groups, there was a clear trend for T subjects to experience the worst of their pain earlier than UT subjects. T subjects reported pain to peak on the 1st day post-exercise for 3 of the 4 SOR tests (figures 4.6, 4.7, 4.8 and 4.9). UT subjects peaked in SOR 2 to 4 days post-exercise. The absence of a delayed peak in SOR for T subjects, similar to that shown in previous studies on untrained subjects (Clarkson et al., 1992; Clarkson & Tremblay, 1988; Nosaka & Sakamoto, 2001), supports the suggestion that training may reduce the amount of secondary damage (Faulkner et al., 1993).

Previous use of a visual analogue scale to report pain had been successful (Nosaka & Clarkson, 1995). However, that study did not compare independent groups of subjects. It appears that this procedure for reporting pain may be valid within subjects but the subjective nature of the scale may prevent accurate comparison between groups. That is to say that a single subject may be able to report the time at which they experience peak SOR in comparison to other testing times but each subject will rate their level of pain differently. These differences may result from factors such as subjects relating the soreness after the exercise bout to physical traumas that they have previously suffered.

5.3 *Circumference (CIR)*

Hypothesis 3 stated that the exercise bout was expected to result in more swelling in the UT group than in the T group. Statistical analysis of the data provided support for the hypothesis.

CIR for the T group had returned to within the normal range after 2 days recovery from exercise. In comparison, CIR for the UT group was still 5% larger after 5 days post-exercise. In addition, UT subjects displayed an increase in CIR on day 1 and then further increases between days 3 and 5 post-exercise. This is consistent with data presented in published literature (Clarkson et al., 1992). It is also an indication that UT subjects suffered secondary damage to the muscles exercised.

Interestingly, the time course of the changes in CIR for the UT group mirrored that of changes in relaxed elbow angle (RANG). The latter have been attributed to swelling but it has since been asserted that the time courses for these 2 variables are different enough to conclude that there is no relationship between them (Clarkson et al., 1992). The results from this study appear to contradict those of Clarkson and coworkers. The similarities in the changes of CIR and RANG from this study indicate that there may well be a relationship between these 2 measures.

The relative lack of swelling for the T group supports the other findings in suggesting that little secondary damage occurred to T subjects. If secondary damage had occurred to T subjects then they would have been likely to show a delayed increase in CIR similar to UT subjects. This would have resulted from an inflammatory response as the damaged tissue was infiltrated by macrophages and phagocytes (Faulkner et al., 1993).

5.4 Range of Motion (ROM)

Hypothesis 4 predicted a larger reduction in ROM of UT subjects compared to T subjects. Statistical analysis demonstrated a significantly ($p<0.033$) larger increase in the flexed arm angle (FANG) of UT subjects compared to T subjects. However, there was no significant difference between the changes in relaxed arm angle (RANG) of both groups.

FANG is a measure of the elbow flexor muscles' ability to contract at a shortened muscle length. Increases in FANG indicate that the subject is unable to voluntary flex their elbow fully (Clarkson et al., 1992). The time course of FANG measurements of both groups appears to reflect the time course of their loss and subsequent recovery in maximal voluntary torque (figures 4.1 and 4.12). Clarkson and colleagues (1992) also reported this similarity between force and FANG. One important difference between the two measures is that both groups experienced a very similar change in FANG immediately post-exercise. This is in contrast to the large differences in peak torque immediately following the eccentric exercise. However, as with the recoveries in strength, T subjects exhibited a faster return to pre-exercise levels while UT subjects remained unable to achieve full elbow flexion.

According to Morgan's popping sarcomere theory, sarcomeres stretched beyond their normal lengths would be unable to create as many cross-bridge attachments and as a result produce less force and not be able to contract as fully (Clarkson et al., 1992). This reasoning is consistent with the similarities observed between the time courses of maximal voluntary torque and FANG. E-C uncoupling may also account for the similarities between torque decrements and increased FANG by impairing the ability of the muscle to contract to its full potential (Clarkson et al., 1992).

As described in the preceding section, RANG mirrors the change in CIR for UT subjects. Although swelling is often implicated in spontaneous muscle shortening, it may not be the cause (Clarkson et al., 1992). It is thought that an accumulation of intracellular calcium the muscle fibre leads to shortening of the muscle fibres. This also follows the time course of secondary damage. Muscle proteins are further degraded, giving rise to an increased intracellular calcium concentration around the same time RANG undergoes delayed decreases (Clarkson et al., 1992).

5.5 Plasma Creatine Kinase (CK) Concentration

The exercise bout did not result in a statistically significant increase in CK concentration for either group, leading to a rejection of hypothesis 5. However, there was a clear trend for the UT group to exhibit larger increases in CK activity than the T group. The likely reason for the lack of a significant difference in CK response between groups was the finding of a large variability in responses amongst the UT group. Large variability of increases in plasma CK following a damaging bout of exercise have been previously reported (Brown, Day, & Donnely, 1999; Nosaka & Clarkson, 1996). A factor that may have added to the variability in the CK measures was the accuracy of the spectrophotometer used. The Reflotron (Boehringer-Mannheim) is a portable device that could only read CK concentrations up to approximately 1,500IU before requiring dilution of the sample in a saline solution.

Some subjects required their blood samples to be diluted as much as a 1: 9 (blood: saline) ratio.

Although the increase in plasma CK concentration is not considered an accurate quantifier of muscle damage, previous research has reported that there was a tendency for the subjects who show large increases in CK concentration to also exhibit large responses in the other criterion measures (Nosaka & Clarkson, 1996). For example, in the present study, the subject who demonstrated the largest increase in CK activity (>10,000IU) also recorded the greatest decline in strength. At no stage during the testing did this subject's isometric 90° torque exceed 50% of his baseline measure.

T subjects were far less variable than UT subjects in their CK response after the exercise intervention. The peak recording of CK activity for the T group occurred on the last of day of their testing (day 5). This was also the time at which the UT group achieved their peak CK concentrations. These time courses are similar to those previously reported in the literature (Clarkson et al., 1992; Nosaka & Sakamoto, 2001; Paddon-Jones et al., 2000).

5.6 *Conclusions*

From the results of this study it can be concluded that a background of heavy resistance training affords a degree of protection against exercise-induced muscle damage, although this is temporal in nature. The muscle functions of T subjects return to baseline levels sooner than those of UT subjects. The small subject numbers and large variability in the responses of the UT subjects may have prevented some results from being statistically significant, both between groups and over time. Therefore, increasing subject numbers in subsequent studies would be of value. Further research into the effect of training history on muscle damage and recovery would be useful in order to compare and contrast the results to those of the present study. Questions arising from the present research relate to the degree of resistance-training needed to result in a protection from damage. In addition, it would be of interest to determine if there is a difference in levels of protection based on the intensity of resistance-training over a similar time period? A more difficult task would be to address some of the theories attempting to explain adaptations to training. Such data would be helpful in the design and periodisation of training programs to elicit peak performance and enhance injury prevention at the appropriate time for optimal competitive results.

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Appendices

Appendix A

Informed consent form and medical questionnaire

Informed Consent Form
Comparison between trained and untrained subjects after eccentric exercise

Purpose of the study
Eccentric exercise (when the muscle produces force as it lengthens) has been shown to result in repairable muscle damage. The purpose of this study is to determine if there will be any difference in the response of subjects' to eccentric exercise due to their training status.

What will happen
If you agree to participate in the study you will be required to attend the laboratory (building 19, Joondalup ECU) on 8 occasions. The exercise day will be the longest time spent in the laboratory (approximately 2 hours) with the other days each only requiring about 15 minutes of your time.

Measurements that will be taken
On your first attendance at the laboratory small dots will be placed on the arm that you will exercise as landmarks for measurements that are to be taken over the next 6 days. For this reason it is vital that these marks are not washed off the skin for the duration of the study. Girth measurements of your upper arm will be taken at 3, 5, 7, 9 and 11cm above the elbow and the angle of your elbow will be measured while you are trying to fully flex the joint, when the joint is fully extended and when it is relaxed by your side. The girth measurements will be taken using a constant tension measuring tape and the elbow angle will be measured with a goniometer (kind of like a protractor) on every attendance at the laboratory.
Another measurement to be taken each day during the study is blood Creatine Kinase (CK) levels. This will be measured using a small sample of blood taken from a finger prick puncture.
The last variable to be measured on each day of the testing will be isometric strength. This requires you to contract against the lever arm of the Cybex machine in a bicep curl motion while your upper arm is supported on the arm curl bench (preacher curl) while the machine measures the amount of force you produce. Isometric strength will be measured at two positions; with your elbow in 90° of flexion and at an elbow angle of 150°.
On the 5 days after the exercise bout some additional measurements will be taken. These are measurements of muscle soreness and tenderness. Muscle soreness will be measured by the investigator extending and flexing your arm at the elbow and you will be asked to mark on a scale what you believe the level of soreness to be. The same type of scale will be used to measure tenderness when the investigator palpates your upper arm and forearm.

The exercise protocol
You will be required to complete 10 sets of 6 maximal eccentric contractions, using one arm only, against the lever arm of a Cybex 6000 isokinetic dynamometer. The Cybex machine will force your arm to straighten at 90° per second (1 second for each eccentric contraction) and there will be 10 seconds rest between each repetition as the machine returns to the staring position. There will also be 3 minutes rest between each set of exercise.

Please note: you will be required to refrain from training for the week of the testing.

Medical Questionnaire

In order to safely carry out the study on muscle damage caused by eccentric exercise please answer the following questions truthfully. The answers will help us to identify any injuries or illnesses that may have an influence on or be aggravated by the study. All information that you provide will be kept strictly confidential and used only for the purposes of this study.

Name: ____

Date of Birth: ______________

Medical History.
Please circle the correct answer; Y = yes, N = no, ? = unsure.
If you answer YES, please give details.

Have you ever suffered from any of the following?

High blood pressure......................Y / N / ? ______________________
Heart abnormalities......................Y / N / ? ______________________
Rheumatic fever..........................Y / N / ? ______________________
Epilepsy.................................Y / N / ? ______________________
Diabetes.................................Y / N / ? ______________________
High cholesterol.........................Y / N / ? ______________________
Asthma...................................Y / N / ? ______________________
Any infectious diseases..................Y / N / ? ______________________
A flu within the last 2 weeks............Y / N / ? ______________________
Any neurological disorders...............Y / N / ? ______________________
Any neuromuscular disorders..............Y / N / ? ______________________
Recurring back pain......................Y / N / ? ______________________
Recurring neck pain......................Y / N / ? ______________________
Any other recurring muscle or
joint injuries...........................Y / N / ? ______________________
Have you recently had any injuries?...Y / N / ? ______________________
Have you had any elbow or
shoulder problems in the past?..........Y / N / ? ______________________
Are you on any medication?..............Y / N / ? ______________________
Do you suffer any other condition
that may affect upper arm exercise?....Y / N / ? ______________________

Lifestyle Habits.

Have you ever participated in resistance training? Yes No
If YES, how long ago and how long for? ____________________________________

____

____

Do you regularly participate in exercise other than resistance training? Yes / No
If YES, what do you do and how many hours per week? ______________________

____

____

Do you smoke tobacco? Yes / No
If YES, how much per day? ____
Do you consume alcohol? Yes / No
If YES, how much per day? ____
Do you drink tea or coffee? Yes / No
If YES, how much per day? ____

Declaration.
The information that I have provided on this form is, to the best of my knowledge, truthful and accurate. I have also read the informed consent form and I understand what is expected of me throughout my participation in the study.

Participant.

Name: ___________________________ Date: ____________________

Signature: __________________________

Researcher.

Name: ___________________________ Date: ____________________

Signature: _________________________

Appendix B

Muscle soreness assessment sheet

MUSCLE SORENESS ASSESSMENT SHEET

Name:__________ **ID#:**__________ **Exercised arm: L R**

Using the visual analog scale provided, please report the extent of your muscle soreness while your upper arm and forearm are being palpated, and while the elbow joint is being extended and flexed by the investigator. The zero on the visual analog scale represents "no pain" while the 100 at the other end of the line represents "unbearably painful". The 100 should be associated with the worst pain that you have ever experienced.

Example

0______________________________100

Pre Post 1h D1 D2 D3 D4 D5

Upper arm

Palpation 1 0______________________________100

Palpation 2 0______________________________100

Palpation 3 0______________________________100

Forearm

Palpation 4 0______________________________100

Extension & Flexion soreness

Extension 0______________________________100

Flexion 0______________________________100

Pre Post 1h D1 D2 D3 D4 D5

Upper arm

Palpation 1 0______________________________100

Palpation 2 0______________________________100

Palpation 3 0______________________________100

Forearm

Palpation 4 0______________________________100

Extension & Flexion soreness

Extension 0______________________________100

Flexion 0______________________________100

Appendix C

Absolute data for each individual subject

Isometric 90° torque (Nm)		Pre	Imm. Post	30 min. post	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
Trained	subject 1	75.14	52.21	46.62	63.4	63.4	66.28	74.59	75.7		
	subject 2	55.01	41.03	39.91	38.23	37.11	44.38	46.62	51.09		
	subject 3	86.33	46.62	48.3	56.13	55.57	60.6	56.69	63.96		
	subject 4	52.77	38.79	36	43.27	47.18	50.54	49.98	51.65		
	subject 5	43.27	35.99	37.11	38.23	41.03	41.03	41.59	41.59		
	subject 6	79.06	55.01	36	65.08	59.49	74.03	81.3	77.94		
	subject 7	66.76	56.69	60.04	58.93	56.69	65.64	70.67	56.69		
	subject 8	73.47	55.01	58.93	70.11	67.32	68.99	71.79	71.79		
Untrained	subject 9	77.94	30.96	38.23	34.32	32.64	34.88	33.2	38.23	34.88	35.44
	subject 10	45.5	28.72	28.72	28.72	26.49	28.17	32.08	34.88	32.64	31.52
	subject 11	64.52		39.35	31.52	36.55	20.89	11.39	24.25	37.67	44.38
	subject 12	66.75	45.5	42.71	44.94	46.62	54.45	56.69	57.81	58.37	56.13
	subject 13	70.11	49.98	46.06	42.15	42.71	46.06	56.13	57.81	60.6	61.72
	subject 14	54.45	38.79	39.91	40.47	43.27	43.27	56.69	58.37	54.45	63.4
	subject 15	53.89	44.94	42.71	39.91	47.18	51.66	55.57	55.57	56.13	57
	subject 16	63.96	35.99	38.79	34.88	38.79		43.26	42.7	44.38	51.66

Isometric 150° torque (Nm)		Pre	Imm. Post	30 min. post	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
Trained	subject 1	57.24	43.26	37.67	48.86	52.77	57.24	62.84	67.87		
	subject 2	46.62	35.4	32.08	27.61	32.08	36.55	39.91	39.91		
	subject 3	66.75	43.26	42.71	44.38	44.38	44.38	38.23	50.54		
	subject 4	38.23	27.05	22.57	25.37	30.96	28.72	32.08	27.61		
	subject 5	35.44	29.28	25.37	28.17	34.88	33.2	34.88	30.96		
	subject 6	52.21	42.71	25.93	44.38	39.35	46.62	56.13	48.86		
	subject 7	47.18	32.08	30.4	35.99	33.2	36	39.91	39.35		
	subject 8	52.77	44.38	49.98	54.45	56.69	53.3	56.13	58.93		
Untrained	subject 9	65.64	25.93	32.08	28.17	29.84	25.37	25.37	24.25	24.25	30.4
	subject 10	33.76	24.81	20.33	15.86	18.66	22.01	16.98	20.34	23.69	23.69
	subject 11	42.71		29.28	22.57	24.81	15.86	8.59	13.06	25.37	30.96
	subject 12	56.13	37.67	33.2	34.32	34.88	43.83	47.74	40.47	47.18	43.27
	subject 13	46.06	32.08	32.08	30.4	30.96	35.44	42.71	42.71	47.18	44.38
	subject 14	35.99	23.13	22.01	28.72	22.01	22.57	35.99	28.72	34.88	31.52
	subject 15	23.13	14.18	17.54	19.22	18.66	22.57	23.13	23.13	23.69	26
	subject 16	41.59	33.76	31.52	30.4	22.57		28.16	24.81	23.69	28.17

30°/second torque (Nm)		Pre	Imm. Post	30 min. post	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
Trained	subject 1	54.84	38.73	32.69	42.76	44.77	47.46	55.01	58.19		
	subject 2	42.76	32.69	36.05	28.66	27.99	32.02	34.7	35.37		
	subject 3	62.89	36.05	35.38	36.05	38.73	39.4	41.42	44.1		
	subject 4	36.05	28.66	26.65	30	33.3	34.7	32.02	38.73		
	subject 5	30.68	29.33	26.65	27.99	30	32.02	34.7	32.69		
	subject 6	46.79	42.09	32.02	50.81	51.48	58.87	58.19	57.52		
	subject 7	54.17	48.13	42.76	48.8	47.46	44.77	54.17	50.81		
	subject 8	51.48	43.43	46.11	48.8	48.13	48.13	52.15	52.15		
Untrained	subject 9	56.85	23.29	27.99	27.99	26.65	30.68	25.31	32.02	21.28	21.95
	subject 10	39.4	34.7	23.97	19.27	22.62	25.31	19.94	25.98	30.68	27.32
	subject 11	42.75		24.64	21.95	24.64	20.61	16.58	19.94	27.99	27.32
	subject 12	47.46	27.99	30	27.32	31.35	36.05	38.73	35.38	45.44	40.74
	subject 13	47.46	34.03	34.03	34.03	34.7	38.73	42.76	44.1	44.1	44.1
	subject 14	35.38	22.62	21.95	26.65	27.32	30.68	30.68	29.33	32.02	36.05
	subject 15	44.77	30	33.36	34.03	34.7	34.03	40.07	36.72	34.03	35
	subject 16	42.09	30	27.99	30	30.68	35.37	40.07	32.02	29.33	28.66

90°/second torque (Nm)		Pre	Imm. Post	30 min. post	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
Trained	subject 1	52.15	38	31.35	42.76	37.39	45.44	50.14	52.83		
	subject 2	42.09	32.02	31.35	26.65	26.65	32.02	32.02	33.36		
	subject 3	61.55	32.69	33.36	32.69	36.05	34.03	34.7	39.4		
	subject 4	35.38	27.32	23.3	27.32	32.69	33.36	30	38.06		
	subject 5	35.38	28.66	25.31	30	32.02	32.69	33.36	30.68		
	subject 6	47.46	40.07	32.02	49.47	53.5	60.88	67.59	71.62		
	subject 7	46.79	46.79	38.73	46.11	48.8	53.5	48.8	48.8		
	subject 8	48.8	42.76	40.74	45.44	47.46	50.14	53.5	58.19		
Untrained	subject 9	52.15	20.61	22.62	23.97	21.95	23.3	22.62	20.61	19.94	17.93
	subject 10	27.32	25.31	23.97	19.94	21.28	22.62	21.28	25.31	29.34	23.3
	subject 11	38.73		23.97	20.61	23.29	20.61	13.23	25.31	29.33	27.99
	subject 12	44.77	26.65	21.28	23.97	26.65	33.36	37.38	31.35	39.4	35.38
	subject 13	52.15	37.39	40.74	30	31.35	38.06	40.07	41.42	40.74	42.76
	subject 14	34.7	19.27	21.28	20.61	21.95	28.66	27.99	30	27.99	30
	subject 15	33.36	26.65	28.66	27.99	34.02	36.72	40.07	34.7	32.69	41
	subject 16	42.09	32.02	30	27.99	25.98	31.35	31.35	30.68	30.68	28.66

150°/second torque (Nm)		Pre	Imm. Post	30 min. post	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
Trained	subject 1	45.44	36.04	27.99	41.41	36.05	41.42	42.76	46.79		
	subject 2	40.74	29.34	29.33	23.3	24.64	29.34	31.35	30.68		
	subject 3	50.14	28.66	28	27.32	28.66	27.32	29.34	31.35		
	subject 4	29.34	23.97	22.62	25.98	27.32	30	25.31	29.33		
	subject 5	30	27.99	23.97	25.31	28.66	28.66	28.66	26.65		
	subject 6	46.79	39.4	32.02	49.47	52.83	54.84	62.22	63.56		
	subject 7	45.44	48.13	45.44	46.11	43.43	53.5	52.83	44.77		
	subject 8	48.13	34.7	36.72	38.73	41.42	42.76	40.07	42.76		
Untrained	subject 9	42.09	20.61	23.97	21.95	27.32	21.28	21.28	21.28	16.58	15.91
	subject 10	23.97	18.59	23.29	17.26	22.62	22.62	23.97	27.32	24.64	25.31
	subject 11	32.69		19.94	20.61	19.27	19.27	17.93	23.97	24.64	27.99
	subject 12	42.09	21.95	23.97	19.94	23.97	27.99	32.02	32.02	34.03	34.03
	subject 13	52.83	38.06	38.06	27.32	32.02	38.06	40.74	40.07	40.74	40.74
	subject 14	33.36	19.27	21.28	21.95	23.97	20.61	24.64	27.99	27.99	28.66
	subject 15	26.65	25.31	23.3	27.32	31.35	29.34	30.68	34.7	32.02	33
	subject 16	39.4	24.64	28.66	27.32	25.31	22.62	33.36	25.31	27.99	24.64

210°/second torque (Nm)		Pre	Imm. Post	30 min. post	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
Trained	subject 1	41.41	33.36	26.65	36.05	34.7	34.7	37.39	43.43		
	subject 2	34.03	27.32	28.66	25.31	23.97	30.68	29.33	25.31		
	subject 3	44.72	25.98	23.97	26.65	25.98	27.32	25.98	27.99		
	subject 4	28.66	25.98	19.94	25.98	30	30.68	23.29	33.36		
	subject 5	28.66	23.96	21.95	23.3	24.64	24.64	23.97	24.64		
	subject 6	43.43	34.7	32.69	46.11	51.48	63.56	56.85	62.22		
	subject 7	44.71	46.11	40.07	48.8	45.54	42.76	48.13	47.46		
	subject 8	39.4	30.68	32.02	38.73	39.4	38.06	36.05	44.77		
Untrained	subject 9	44.1	18.6	22.62	25.31	18.6	17.26	14.57	13.23	14.57	13.89
	subject 10	22.62	14.57	22.62	21.28	18.6	25.31	24.64	27.32	27.32	25.31
	subject 11	28.66		19.94	15.91	17.25	16.58	17.25	22.62	23.97	24.64
	subject 12	36.05	21.95	20.61	17.93	24.64	26.65	30		32.02	30
	subject 13	48.8	40.07	40.74	40.07	34.7	36.72	38.06	43.43	43.43	40.74
	subject 14	32.69	17.93	23.29	20.61	25.31	21.95	25.31	28.66	25.31	25.98
	subject 15	30	23.97	21.28	27.32	25.98	26.65	22.97	29.34	27.32	33
	subject 16	38.06	27.32	20.61	21.95	23.97	19.27	23.97	19.27	22.62	22.62

300°/second torque (Nm)		Pre	Imm. Post	30 min. post	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
Trained	subject 1	38.73	30	25.97	34.03	30.68	35.37	34.7	38.06		
	subject 2	32.02	24.64	23.97	24.64	22.62	25.31	29.33	27.32		
	subject 3	33.36	19.94	18.6	23.97	21.95	21.28	22.62	21.28		
	subject 4	32.02	23.97	21.95	22.62	26.65	25.31	20.61	34.03		
	subject 5	26.65	22.62	21.28	20.61	23.3	24.64	23.97	21.95		
	subject 6	37.39	34.03	30	45.44	38.73	55.51	50.81	58.87		
	subject 7	45.44	45.44	36.05	46.79	40.07	46.11	44.77	42.76		
	subject 8	32.69	24.64	29.34	32.69	32.02	31.35	34.7	42.09		
Untrained	subject 9	40.07	15.91	19.27	20.61	16.58	12.56	15.24	17.26	10.54	11.21
	subject 10	20.61	18.59	19.94	18.6	21.28	21.28	24.64	26.65	25.98	21.95
	subject 11	25.31		17.25	12.55	14.57	19.27	17.25	22.62	20.61	19.94
	subject 12	27.99	19.27	18.6	15.24	19.27	20.61	25.31	23.97	27.99	28.66
	subject 13	45.44	34.7	40.07	36.72	38.06	36.72	36.72	38.73	44.1	40.74
	subject 14	30.68	21.28	22.62	17.25	21.95	23.97	25.31	25.98	25.31	27.99
	subject 15	25.31	23.97	25.31	21.95	27.32	24.64	26.65	27.99	28.66	27
	subject 16	32.02	21.95	23.29	21.95	21.95	18.59	20.61	15.24	21.28	20.61

Change in FANG (°)		Pre	Imm. Post	30 min. post	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
Trained	subject 1	0	8	6.5	7	3.5	1	-1.5	-1.5		
	subject 2	0	8	7.5	6.5	3.5	2.5	1.5	1.5		
	subject 3	0	10	9.5	2.5	3	0.5	-1.5	0.5		
	subject 4	0	16.5	12	2	4	3	-1.5	1		
	subject 5	0	4.5	3.5	3.5	-1	-1	-0.5	-0.5		
	subject 6	0	12.5	12	8.5	4	1.5	2.5	4.5		
	subject 7	0	5	4	1	3	2	3.5	2		
	subject 8	0	5	2	0.5	1.5	-1.5	-4	-4		
Untrained	subject 9	0	12.5	10.5	11	12.5	14	9	8.5	9.5	6.5
	subject 10	0	12.5	11.5	15.5	11	7.5	6.5	8	7.5	7.5
	subject 11	0	10	5	7	7	15.5	21.5	19.5	13.5	0
	subject 12	0	9	8	9	6.5	3	1	0	0.5	1
	subject 13	0	10.5	4.5	8.5	6.5	7.5	5.5	2.5	1.5	1.5
	subject 14	0	1.5	0.5	2	4.5	1	-1	-2.5	-0.5	-4
	subject 15	0	7	5.5	4	3	1.5	2	4	2.5	3
	subject 16	0	11.5	-1.5	-2.5	16.5	14	14.5	11.5	9.5	10.5

Change in RANG (°)		Pre	Imm. Post	30 min. post	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
Trained	subject 1	0	1	-3	-0.5	-5	-2	-2	-2.5		
	subject 2	0	-4	-2.5	-1	-3	-3.5	1	-2.5		
	subject 3	0	-3	-3	-2	-2	-8.5	-2	-1		
	subject 4	0	-7	-7	-11	-3	-6.5	-2	0		
	subject 5	0	-5	-4	-3	1	-1.5	-3	2		
	subject 6	0	0.5	2	-5	-3	-5.5	-5	-2.5		
	subject 7	0	3	2	1.5	0	0	0	1		
	subject 8	0	-2.5	-3	-1	4	3.5	4	0		
Untrained	subject 9	0	-12	-1	-9.5	-3	-28	-11.5	-4	-9	-1
	subject 10	0	-1	1	-2	-5	-10	-9	-8	-6	-8.5
	subject 11	0	-25.5	-10	-19.5	-17.5	-43.5	-68.5	-61.5	-49.5	-26.5
	subject 12	0	0	-2	-3	-3	1	-7	3	-4	-3
	subject 13	0	1	3	1	0	1.5	4	2	5	7.5
	subject 14	0	-5	-6	-7.5	-6	-9	-4.5	-3	1.5	4
	subject 15	0	-1	0	-6.5	-0.5	1	2	-0.5	-4.5	3
	subject 16	0	-2	-3	-5	-5	-5	-4	-4.5	-3	-5

CIR (cm)		Pre	Imm. Post	30 min. post	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
Trained	subject 1	32.8	32.88	33.12	34.11	34.35	33.82	33.68	33.98		
	subject 2	29.73	30.35	30.08	30.67	30.1	30.28	30.24	30.18		
	subject 3	30.06	30.32	30.92	30.83	31.11	31.14	30.54	30.64		
	subject 4	26.15	26.73	26.12	26.78	26.53	26.51	26.47	26.26		
	subject 5	29.6	29.73	29.79	30	29.22	29.64	29.64	29.61		
	subject 6	31.25	31.4	31.36	31.42	31.21	31.11	31.2	31.49		
	subject 7	26.62	26.82	26.73	26.83	26.58	26.24	26.58	26.51		
	subject 8	33.01	32.78	32.57	32.89	33.17	32.11	32.52	33.18		
Untrained	subject 9	27.69	28.67	28.14	28.75	29.23	30.46	30.38	30.25	30.4	30.27
	subject 10	26.46	26.76	26.9	27.47	27.28	27.32	27.71	28.01	28.17	28.18
	subject 11	25.09	25.85	25.97	26.17	26.18	27.17	28.79	28.81	28.02	27.63
	subject 12	27.36	27.93	27.63	28.2	28.05	28.39	28.28	28.54	29.02	28.67
	subject 13	35.73	37.17	37	37.08	37.36	37.11	37.05	36.9	36.97	36.61
	subject 14	26.57	27.02	26.84	27.56	27.47	27.27	27.39	27.23	26.84	27
	subject 15	27.45	27.37	27.47	28.13	28.11	28.05	27.59	27.87	27.59	27.62
	subject 16	29.9	29.6	29.62	30.07	29.99	29.87	29.64	29.72	30.15	29.96

Extension SOR (mm)		Pre	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
Trained	subject 1	0	60	58	11	0	0		
	subject 2	0	7	23	17	14	5		
	subject 3	0	5	7	4	12	1		
	subject 4	0	76	75	37	2	0		
	subject 5	0	25	7	0	0	0		
	subject 6	0	6	7	6	8	3		
	subject 7	0	10	1	0	0	0		
	subject 8	0	4	2	5	2	0		
Untrained	subject 9	0	15	30	25	7	7	1	0
	subject 10	0	8	58	35	64	70	51	17
	subject 11	0	10	51	73	89	68	52	43
	subject 12	0	9	8	4	5	1	0	0
	subject 13	0	26	25	13	10	3	0	0
	subject 14	0	31	31	30	14	7	0	1
	subject 15	0	39	40	18	19	2	4	0
	subject 16	0	3	13	2	0	0	0	0

Flexion SOR (mm)		Pre	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
Trained	subject 1	0	0	0	0	0	0		
	subject 2	0	6	18	10	4	4		
	subject 3	0	6	7	6	1	1		
	subject 4	0	21	15	1	0	1		
	subject 5	0	3	2	0	0	0		
	subject 6	0	14	10	7	3	5		
	subject 7	0	0	0	0	0	0		
	subject 8	0	13	1	3	2	0		
Untrained	subject 9	0	10	1	10	2	1	0	1
	subject 10	0	2	11	3	11	6	1	2
	subject 11	0	11	24	54	85	43	14	11
	subject 12	0	12	10	6	14	1	0	1
	subject 13	0	3	3	2	1	0	0	0
	subject 14	0	31	37	41	19	8	0	1
	subject 15	0	4	2	0	0	0	0	0
	subject 16	0	0	3	1	0	0	0	0

Upper arm SOR (mm)		Pre	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
Trained	subject 1	0	42.67	52.67	46.67	17.33	1.33		
	subject 2	0	18.33	32.67	49.00	39.67	17.33		
	subject 3	0	19.33	32.00	20.33	5.00	2.33		
	subject 4	0	25.67	31.67	14.00	6.67	4.33		
	subject 5	0	37.67	17.67	7.33	0.00	0.00		
	subject 6	0	25.67	24.33	16.33	6.67	5.00		
	subject 7	0	4.67	8.33	4.67	0.00	0.67		
	subject 8	0	48.33	34.33	20.67	5.67	6.33		
Untrained	subject 9	0	15.00	10.67	20.33	3.33	3.67	2.67	1.00
	subject 10	0	16.67	34.67	16.33	40.00	25.67	12.67	9.00
	subject 11	0	18.33	51.67	74.00	79.33	57.00	33.33	17.00
	subject 12	0	18.33	28.00	20.00	14.67	9.00	4.67	1.33
	subject 13	0	7.00	12.00	11.67	5.33	1.67	0.67	0.00
	subject 14	0	43.67	46.67	56.67	29.67	21.67	5.67	2.00
	subject 15	0	44.33	58.00	40.33	27.67	30.33	12.67	6.00
	subject 16	0	1.33	2.67	2.67	0.67	0.00	0.00	0.00

Forearm SOR (mm)		Pre	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
Trained	subject 1	0	66	54	21	0	0		
	subject 2	0	16	17	14	6	1		
	subject 3	0	12	11	9	3	1		
	subject 4	0	64	72	32	14	14		
	subject 5	0	54	14	3	0	0		
	subject 6	0	9	11	6	14	4		
	subject 7	0	19	12	0	0	0		
	subject 8	0	39	2	5	2	0		
Untrained	subject 9	0	4	12	9	7	0	0	0
	subject 10	0	20	44	39	55	42	17	8
	subject 11	0	11	40	44	63	55	35	15
	subject 12	0	50	9	22	12	1	0	1
	subject 13	0	1	9	14	8	5	1	0
	subject 14	0	12	15	25	18	9	1	0
	subject 15	0	45	32	47	5	6	3	2
	subject 16	0	7	5	2	1	0	0	0

CK (IU)		Pre	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
Trained	subject 1	134	503	387	240	286	248		
	subject 2	293	799	642	1080	1460	2280		
	subject 3	762	927	575	2140	2420	2380		
	subject 4	784	776	531	403	300	292		
	subject 5	159	262	220	288	220	257		
	subject 6	226		193	209	126	87.6		
	subject 7	652	419	345	367	312	307		
	subject 8	174	257	398	446	224	211		
Untrained	subject 9	180	1940	6320	10000	10000	9780	6086	3462
	subject 10	282	496	300	480	2160	4080	6240	3868
	subject 11	71	133	232	1250	6080	8000	6800	5640
	subject 12	168	241	198	260	418	555	593	606
	subject 13	112	340	270	855	1080	652	777	577
	subject 14	124	482	476	310	263	334	751	555
	subject 15	320	228	139	100	203	169	265	200
	subject 16	52.3	186	85.4	223	185	175	160	170

Appendix D

Normalised data for each individual subject (selected measures only)

Isometric 90° torque (% of pre)		Pre	Imm. Post	30 min. po	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
Trained	subject 1	100	69.48363	62.04418	84.37583	84.37583	88.20868	99.26803	100.7453		
	subject 2	100	74.58644	72.55045	69.49646	67.46046	80.67624	84.74823	92.87402		
	subject 3	100	54.00209	55.94811	65.01795	64.36928	70.19576	65.66663	74.0878		
	subject 4	100	73.50767	68.22058	81.99735	89.40686	95.77411	94.71291	97.87758		
	subject 5	100	83.17541	85.76381	88.35221	94.8232	94.8232	96.1174	96.1174		
	subject 6	100	69.58007	45.53504	82.31723	75.24665	93.63774	102.8333	98.58335		
	subject 7	100	84.91612	89.93409	88.27142	84.91612	98.32235	105.8568	84.91612		
	subject 8	100	74.8741	80.20961	95.4267	91.62924	93.90227	97.71335	97.71335		
Untrained	subject 9	100	39.72286	49.05055	44.03387	41.87837	44.75237	42.59687	49.05055	44.75237	45.47088
	subject 10	100	63.12088	63.12088	63.12088	58.21978	61.91209	70.50549	76.65934	71.73626	69.27473
	subject 11	100	0	60.98884	48.85307	56.6491	32.37756	17.65344	37.58524	58.385	68.78487
	subject 12	100	68.16479	63.98502	67.32584	69.8427	81.57303	84.92884	86.60674	87.44569	84.08989
	subject 13	100	71.28798	65.69676	60.11981	60.91856	65.69676	80.05991	82.45614	86.4356	88.03309
	subject 14	100	71.23967	73.2966	74.32507	79.4674	79.4674	104.1139	107.1993	100	116.4371
	subject 15	100	83.3921	79.25404	74.05827	87.54871	95.86194	103.1175	103.1175	104.1566	105.771
	subject 16	100	56.26954	60.64728	54.53408	60.64728	0	67.63602	66.76048	69.38712	80.76923

Isometric 150° torque (% of pre)		Pre	Imm. Post	30 min. po	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
Trained	subject 1	100	75.57652	65.81062	85.35989	92.19078	100	109.7834	118.5709		
	subject 2	100	75.93308	68.81167	59.22351	68.81167	78.39983	85.60704	85.60704		
	subject 3	100	64.80899	63.98502	66.48689	66.48689	66.48689	57.27341	75.71536		
	subject 4	100	70.75595	59.03741	66.3615	80.98352	75.12425	83.91316	72.22077		
	subject 5	100	82.61851	71.58578	79.48646	98.41986	93.67946	98.41986	87.35892		
	subject 6	100	81.80425	49.66482	85.00287	75.3687	89.29324	107.5081	93.5836		
	subject 7	100	67.99491	64.43408	76.28232	70.3688	76.30352	84.59093	83.40398		
	subject 8	100	84.10081	94.71291	103.1836	107.4285	101.0044	106.3673	111.6733		
Untrained	subject 9	100	39.50335	48.87264	42.9159	45.46009	38.65021	38.65021	36.94394	36.94394	46.31322
	subject 10	100	73.48934	60.21919	46.97867	55.27251	65.1955	50.29621	60.24882	70.1718	70.1718
	subject 11	100	0	68.55537	52.84477	58.08944	37.13416	20.11239	30.57832	59.40061	72.48888
	subject 12	100	67.11206	59.14841	61.14377	62.14146	78.08658	85.05256	72.10048	84.05487	77.0889
	subject 13	100	69.64828	69.64828	66.00087	67.21667	76.94312	92.72688	92.72688	102.4316	96.35258
	subject 14	100	64.26785	61.15588	79.79994	61.15588	62.71186	100	79.79994	96.91581	87.57988
	subject 15	100	61.30566	75.83225	83.09555	80.67445	97.5789	100	100	102.4211	112.4081
	subject 16	100	81.17336	75.78745	73.09449	54.26785		67.70858	59.65376	56.96081	67.73263

30°/second torque (% of pre)		Pre	Imm. Post	30 min. po	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
Trained	subject 1	100	70.62363	59.60977	77.97228	81.63749	86.54267	100.31	106.1087		
	subject 2	100	76.44995	84.30776	67.02526	65.45837	74.88307	81.15061	82.71749		
	subject 3	100	57.32231	56.25696	57.32231	61.58372	62.64907	65.86103	70.12244		
	subject 4	100	79.50069	73.9251	83.21775	92.37171	96.2552	88.82108	107.4341		
	subject 5	100	95.59974	86.86441	91.23207	97.78357	104.3677	113.103	106.5515		
	subject 6	100	89.95512	68.43343	108.5916	110.0235	125.8175	124.3642	122.9323		
	subject 7	100	88.84992	78.93668	90.08676	87.61307	82.64722	100	93.7973		
	subject 8	100	84.36286	89.56876	94.79409	93.49262	93.49262	101.3015	101.3015		
Untrained	subject 9	100	40.96746	49.23483	49.23483	46.87775	53.96658	44.52067	56.32366	37.43184	38.61038
	subject 10	100	88.07107	60.83756	48.90863	57.41117	64.23858	50.60914	65.93909	77.86802	69.3401
	subject 11	100	0	57.63743	51.34503	57.63743	48.21053	38.78363	46.64327	65.47368	63.90643
	subject 12	100	58.97598	63.21113	57.56426	66.05563	75.9587	81.60556	74.54699	95.74378	85.84071
	subject 13	100	71.70249	71.70249	71.70249	73.1142	81.60556	90.09692	92.92035	92.92035	92.92035
	subject 14	100	63.93443	62.0407	75.32504	77.21877	86.71566	86.71566	82.89994	90.50311	101.8937
	subject 15	100	67.00916	74.51418	76.01072	77.50726	76.01072	89.5019	82.01921	76.01072	78.17735
	subject 16	100	71.27584	66.50036	71.27584	72.89142	84.03421	95.20076	76.07508	69.68401	68.09218

90°/second torque (% of pre)		Pre	Imm. Post	30 min. po	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
Trained	subject 1	100	72.86673	60.11505	81.99425	71.69703	87.13327	96.14573	101.3039		
	subject 2	100	76.07508	74.48325	63.3167	63.3167	76.07508	76.07508	79.25873		
	subject 3	100	53.11129	54.19984	53.11129	58.57027	55.28838	56.37693	64.013		
	subject 4	100	77.21877	65.85642	77.21877	92.39683	94.29056	84.79367	107.5749		
	subject 5	100	81.00622	71.53759	84.79367	90.50311	92.39683	94.29056	86.71566		
	subject 6	100	84.42899	67.46734	104.2351	112.7265	128.2764	142.4147	150.906		
	subject 7	100	100	82.7741	98.5467	104.2958	114.3407	104.2958	104.2958		
	subject 8	100	87.62295	83.48361	93.11475	97.2541	102.7459	109.6311	119.2418		
Untrained	subject 9	100	39.52061	43.37488	45.96357	42.09012	44.67881	43.37488	39.52061	38.23586	34.38159
	subject 10	100	92.64275	87.73792	72.98682	77.89165	82.79649	77.89165	92.64275	107.3939	85.28551
	subject 11	100	0	61.89001	53.21456	60.13426	53.21456	34.15957	65.34986	75.72941	72.26956
	subject 12	100	59.52647	47.53183	53.54032	59.52647	74.51418	83.49341	70.02457	88.00536	79.02613
	subject 13	100	71.69703	78.12081	57.52637	60.11505	72.98178	76.83605	79.42474	78.12081	81.99425
	subject 14	100	55.53314	61.32565	59.39481	63.25648	82.59366	80.66282	86.45533	80.66282	86.45533
	subject 15	100	79.88609	85.91127	83.90288	101.9784	110.0719	120.1139	104.0168	97.99161	122.9017
	subject 16	100	76.07508	71.27584	66.50036	61.72488	74.48325	74.48325	72.89142	72.89142	68.09218

150°/second torque (% of pre)		Pre	Imm. Post	30 min. po	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
Trained	subject 1	100	79.31338	61.59771	91.13116	79.33539	91.15317	94.10211	102.971		
	subject 2	100	72.01767	71.99313	57.19195	60.4811	72.01767	76.9514	75.30682		
	subject 3	100	57.15995	55.84364	54.48744	57.15995	54.48744	58.51615	62.52493		
	subject 4	100	81.69734	77.09611	88.54806	93.1152	102.2495	86.26449	99.96592		
	subject 5	100	93.3	79.9	84.36667	95.53333	95.53333	95.53333	88.83333		
	subject 6	100	84.20603	68.43343	105.7277	112.9087	117.2045	132.9771	135.841		
	subject 7	100	105.9199	100	101.4745	95.57658	117.7377	116.2632	98.52553		
	subject 8	100	72.09641	76.29337	80.46956	86.05859	88.84272	83.25369	88.84272		
Untrained	subject 9	100	48.9665	56.94939	52.15015	64.90853	50.55833	50.55833	50.55833	39.39178	37.79995
	subject 10	100	77.55528	97.16312	72.00668	94.36796	94.36796	100	113.9758	102.7952	105.5903
	subject 11	100	0	60.99725	63.0468	58.94769	58.94769	54.84858	73.32518	75.37473	85.62251
	subject 12	100	52.15015	56.94939	47.37467	56.94939	66.50036	76.07508	76.07508	80.85056	80.85056
	subject 13	100	72.0424	72.0424	51.71304	60.6095	72.0424	77.11528	75.84706	77.11528	77.11528
	subject 14	100	57.76379	63.78897	65.79736	71.85252	61.78058	73.86091	83.90288	83.90288	85.91127
	subject 15	100	94.97186	87.42964	102.5141	117.636	110.0938	115.122	130.2064	120.1501	123.8274
	subject 16	100	62.53807	72.74112	69.3401	64.23858	57.41117	84.67005	64.23858	71.04061	62.53807

210°/second torque (% of pre)		Pre	Imm. Post	30 min. po	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
Trained	subject 1	100	80.56025	64.35644	87.05627	83.79618	83.79618	90.2922	104.878		
	subject 2	100	80.2821	84.21981	74.37555	70.43785	90.15574	86.18866	74.37555		
	subject 3	100	58.09481	53.60018	59.59302	58.09481	61.09123	58.09481	62.58945		
	subject 4	100	90.64899	69.57432	90.64899	104.6755	107.0482	81.26308	116.3992		
	subject 5	100	83.60084	76.58758	81.29798	85.97348	85.97348	83.63573	85.97348		
	subject 6	100	79.89869	75.27055	106.1708	118.5356	146.3504	130.9003	143.265		
	subject 7	100	103.1313	89.62201	109.1478	101.8564	95.63856	107.6493	106.1507		
	subject 8	100	77.86802	81.26904	98.29949	100	96.59898	91.49746	113.6294		
Untrained	subject 9	100	42.17687	51.29252	57.39229	42.17687	39.13832	33.03855	30	33.03855	31.4966
	subject 10	100	64.41202	100	94.07604	82.22812	111.8921	108.9302	120.7781	120.7781	111.8921
	subject 11	100	0	69.57432	55.51291	60.18842	57.85066	60.18842	78.92533	83.63573	85.97348
	subject 12	100	60.88766	57.1706	49.73648	68.34951	73.9251	83.21775	0	88.82108	83.21775
	subject 13	100	82.11066	83.48361	82.11066	71.10656	75.2459	77.9918	88.9959	88.9959	83.48361
	subject 14	100	54.84858	71.24503	63.0468	77.42429	67.14592	77.42429	87.67207	77.42429	79.47385
	subject 15	100	79.9	70.93333	91.06667	86.6	88.83333	76.56667	97.8	91.06667	110
	subject 16	100	71.7814	54.15134	57.6721	62.97951	50.63058	62.97951	50.63058	59.43248	59.43248

300°/second torque (% of pre)		Pre	Imm. Post	30 min. po	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
Trained	subject 1	100	77.45933	67.05396	87.8647	79.21508	91.32455	89.59463	98.27007		
	subject 2	100	76.95191	74.85946	76.95191	70.64335	79.04435	91.599	85.32167		
	subject 3	100	59.77218	55.7554	71.85252	65.79736	63.78897	67.80576	63.78897		
	subject 4	100	74.85946	68.55091	70.64335	83.22923	79.04435	64.36602	106.2773		
	subject 5	100	84.87805	79.84991	77.33583	87.42964	92.45779	89.94371	82.36398		
	subject 6	100	91.01364	80.23536	121.5298	103.5838	148.4622	135.8919	157.4485		
	subject 7	100	100	79.33539	102.971	88.18222	101.4745	98.52553	94.10211		
	subject 8	100	75.37473	89.75222	100	97.95044	95.90089	106.1487	128.755		
Untrained	subject 9	100	39.70552	48.09084	51.43499	41.37759	31.34515	38.03344	43.07462	26.30397	27.97604
	subject 10	100	90.19893	96.74915	90.24745	103.2508	103.2508	119.5536	129.3062	126.0553	106.5017
	subject 11	100	0	68.15488	49.58514	57.56618	76.13591	68.15488	89.37179	81.43026	78.78309
	subject 12	100	68.84602	66.4523	54.44802	68.84602	73.63344	90.42515	85.63773	100	102.3937
	subject 13	100	76.36444	88.18222	80.80986	83.7588	80.80986	80.80986	85.23327	97.05106	89.65669
	subject 14	100	69.36115	73.72881	56.22555	71.54498	78.12907	82.49674	84.68057	82.49674	91.23207
	subject 15	100	94.70565	100	86.72461	107.9415	97.35282	105.2944	110.5887	113.2359	106.6772
	subject 16	100	68.55091	72.73579	68.55091	68.55091	58.05746	64.36602	47.59525	66.45846	64.36602

CIR (% of pre)		Pre	Imm. Post	30 min. po	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
Trained	subject 1	100	100.2439	100.9756	103.9939	104.7256	103.1098	102.6829	103.5976		
	subject 2	100	102.0854	101.1773	103.1618	101.2445	101.85	101.7154	101.5136		
	subject 3	100	100.8649	102.8609	102.5615	103.493	103.5928	101.5968	101.9295		
	subject 4	100	102.218	99.88528	102.4092	101.4532	101.3767	101.2237	100.4207		
	subject 5	100	100.4392	100.6419	101.3514	98.71622	100.1351	100.1351	100.0338		
	subject 6	100	100.48	100.352	100.544	99.872	99.552	99.84	100.768		
	subject 7	100	100.7513	100.4132	100.7889	99.84974	98.5725	99.84974	99.58678		
	subject 8	100	99.30324	98.66707	99.63647	100.4847	97.27355	98.5156	100.515		
Untrained	subject 9	100	103.5392	101.6251	103.8281	105.5616	110.0036	109.7147	109.2452	109.7869	109.3174
	subject 10	100	101.1338	101.6629	103.8171	103.099	103.2502	104.7241	105.8579	106.4626	106.5004
	subject 11	100	103.0291	103.5074	104.3045	104.3444	108.2902	114.7469	114.8266	111.678	110.1236
	subject 12	100	102.0833	100.9868	103.0702	102.5219	103.7646	103.3626	104.3129	106.0673	104.788
	subject 13	100	104.0302	103.5544	103.7783	104.562	103.8623	103.6944	103.2746	103.4705	102.4629
	subject 14	100	101.6936	101.0162	103.726	103.3873	102.6346	103.0862	102.484	101.0162	101.6184
	subject 15	100	99.70856	100.0729	102.4772	102.4044	102.1858	100.51	101.5301	100.51	100.6193
	subject 16	100	98.99666	99.06355	100.5686	100.301	99.89967	99.13043	99.39799	100.8361	100.2007

Appendix E

One-way repeated measures ANOVA's with simple contrasts

Isometric 90° torque

GROUPING = trained

Tests of Within-Subjects Contrasts[a]

Measure: MEASURE_1

Source	TIME	Type III Sum of Squares	df	Mean Square	F	Sig.
TIME	Level 2 vs. Level 1	2829.776	1	2829.776	26.864	.001
	Level 3 vs. Level 1	3565.901	1	3565.901	18.467	.004
	Level 4 vs. Level 1	1211.058	1	1211.058	16.818	.005
	Level 5 vs. Level 1	1352.520	1	1352.520	15.511	.006
	Level 6 vs. Level 1	454.813	1	454.813	6.992	.033
	Level 7 vs. Level 1	186.052	1	186.052	1.634	.242
	Level 8 vs. Level 1	214.245	1	214.245	3.645	.098
Error(TIME)	Level 2 vs. Level 1	737.351	7	105.336		
	Level 3 vs. Level 1	1351.692	7	193.099		
	Level 4 vs. Level 1	504.068	7	72.010		
	Level 5 vs. Level 1	610.373	7	87.196		
	Level 6 vs. Level 1	455.333	7	65.048		
	Level 7 vs. Level 1	796.907	7	113.844		
	Level 8 vs. Level 1	411.410	7	58.773		

a. GROUPING = trained

GROUPING = untrained

Tests of Within-Subjects Contrasts[a]

Measure: MEASURE_1

Source	TIME	Type III Sum of Squares	df	Mean Square	F	Sig.
TIME	Level 2 vs. Level 1	2805.844	1	2805.844	16.219	.010
	Level 3 vs. Level 1	2829.682	1	2829.682	27.130	003
	Level 4 vs. Level 1	3179.983	1	3179.983	24.364	.004
	Level 5 vs. Level 1	2804.979	1	2804.979	15.008	.012
	Level 6 vs. Level 1	2022.170	1	2022.170	10.193	.024
	Level 7 vs. Level 1	1021.293	1	1021.293	3.486	.121
	Level 8 vs. Level 1	725.340	1	725.340	2.988	.144
Error(TIME)	Level 2 vs. Level 1	864.963	5	172.993		
	Level 3 vs. Level 1	521.499	5	104.300		
	Level 4 vs. Level 1	652.608	5	130.522		
	Level 5 vs. Level 1	934.485	5	186.897		
	Level 6 vs. Level 1	991.980	5	198.396		
	Level 7 vs. Level 1	1464.955	5	292.991		
	Level 8 vs. Level 1	1213.731	5	242.746		

a. GROUPING = untrained

Isometric 150° torque

GROUPING = trained

Tests of Within-Subjects Contrasts[a]

Measure: MEASURE_1

Source	TIME	Type III Sum of Squares	df	Mean Square	F	Sig.
TIME	Level 2 vs. Level 1	1225.620	1	1225.620	43.095	.000
	Level 3 vs. Level 1	2103.734	1	2103.734	37.261	.000
	Level 4 vs. Level 1	951.134	1	951.134	17.139	.004
	Level 5 vs. Level 1	650.342	1	650.342	8.912	.020
	Level 6 vs. Level 1	456.473	1	456.473	8.042	.025
	Level 7 vs. Level 1	164.984	1	164.984	1.371	.280
	Level 8 vs. Level 1	131.301	1	131.301	1.725	.230
Error(TIME)	Level 2 vs. Level 1	199.079	7	28.440		
	Level 3 vs. Level 1	395.215	7	56.459		
	Level 4 vs. Level 1	388.467	7	55.495		
	Level 5 vs. Level 1	510.820	7	72.974		
	Level 6 vs. Level 1	397.328	7	56.761		
	Level 7 vs. Level 1	842.436	7	120.348		
	Level 8 vs. Level 1	532.816	7	76.117		

a. GROUPING = trained

GROUPING = untrained

Tests of Within-Subjects Contrasts[a]

Measure: MEASURE_1

Source	TIME	Type III Sum of Squares	df	Mean Square	F	Sig.
TIME	Level 2 vs. Level 1	1765.078	1	1765.078	13.102	.015
	Level 3 vs. Level 1	1784.340	1	1784.340	18.974	.007
	Level 4 vs. Level 1	1803.360	1	1803.360	12.698	.016
	Level 5 vs. Level 1	1862.082	1	1862.082	17.160	.009
	Level 6 vs. Level 1	1317.794	1	1317.794	7.433	.041
	Level 7 vs. Level 1	788.677	1	788.677	3.297	.129
	Level 8 vs. Level 1	1095.931	1	1095.931	4.952	.077
Error(TIME)	Level 2 vs. Level 1	673.603	5	134.721		
	Level 3 vs. Level 1	470.212	5	94.042		
	Level 4 vs. Level 1	710.104	5	142.021		
	Level 5 vs. Level 1	542.562	5	108.512		
	Level 6 vs. Level 1	886.425	5	177.285		
	Level 7 vs. Level 1	1196.179	5	239.236		
	Level 8 vs. Level 1	1106.608	5	221.322		

a. GROUPING = untrained

30°/second torque

GROUPING = trained

Tests of Within-Subjects Contrasts[a]

Measure: MEASURE_1

Source	TIME	Type III Sum of Squares	df	Mean Square	F	Sig.
TIME	Level 2 vs. Level 1	811.038	1	811.038	12.614	.009
	Level 3 vs. Level 1	1283.978	1	1283.978	18.333	.004
	Level 4 vs. Level 1	541.041	1	541.041	6.108	.043
	Level 5 vs. Level 1	417.605	1	417.605	5.111	.058
	Level 6 vs. Level 1	223.556	1	223.556	2.094	.191
	Level 7 vs. Level 1	37.411	1	37.411	.402	.546
	Level 8 vs. Level 1	12.751	1	12.751	.164	.698
Error(TIME)	Level 2 vs. Level 1	450.093	7	64.299		
	Level 3 vs. Level 1	490.248	7	70.035		
	Level 4 vs. Level 1	620.100	7	88.586		
	Level 5 vs. Level 1	571.926	7	81.704		
	Level 6 vs. Level 1	747.164	7	106.738		
	Level 7 vs. Level 1	651.352	7	93.050		
	Level 8 vs. Level 1	544.241	7	77.749		

a. GROUPING = trained

GROUPING = untrained

Tests of Within-Subjects Contrasts[a]

Measure: MEASURE_1

Source	TIME	Type III Sum of Squares	df	Mean Square	F	Sig.
TIME	Level 2 vs. Level 1	1753.173	1	1753.173	21.834	.003
	Level 3 vs. Level 1	1860.482	1	1860.482	54.431	.000
	Level 4 vs. Level 1	1860.482	1	1860.482	37.043	.001
	Level 5 vs. Level 1	1586.722	1	1586.722	29.222	.002
	Level 6 vs. Level 1	973.736	1	973.736	19.562	.004
	Level 7 vs. Level 1	821.889	1	821.889	7.064	.038
	Level 8 vs. Level 1	866.026	1	866.026	17.879	.006
Error(TIME)	Level 2 vs. Level 1	481.775	6	80.296		
	Level 3 vs. Level 1	205.082	6	34.180		
	Level 4 vs. Level 1	301.348	6	50.225		
	Level 5 vs. Level 1	325.793	6	54.299		
	Level 6 vs. Level 1	298.658	6	49.776		
	Level 7 vs. Level 1	698.138	6	116.356		
	Level 8 vs. Level 1	290.626	6	48.438		

a. GROUPING = untrained

90°/second torque

GROUPING = trained

Tests of Within-Subjects Contrasts[a]

Measure: MEASURE_1

Source	TIME	Type III Sum of Squares	df	Mean Square	F	Sig.
TIME	Level 2 vs. Level 1	826.008	1	826.008	11.343	.012
	Level 3 vs. Level 1	1608.579	1	1608.579	32.196	.001
	Level 4 vs. Level 1	597.888	1	597.888	6.235	.041
	Level 5 vs. Level 1	378.675	1	378.675	3.361	.109
	Level 6 vs. Level 1	94.806	1	94.806	.634	.452
	Level 7 vs. Level 1	47.483	1	47.483	.267	.621
	Level 8 vs. Level 1	1.394	1	1.394	.008	.933
Error(TIME)	Level 2 vs. Level 1	509.735	7	72.819		
	Level 3 vs. Level 1	349.737	7	49.962		
	Level 4 vs. Level 1	671.277	7	95.897		
	Level 5 vs. Level 1	788.669	7	112.667		
	Level 6 vs. Level 1	1047.206	7	149.601		
	Level 7 vs. Level 1	1243.257	7	177.608		
	Level 8 vs. Level 1	1271.094	7	181.585		

a. GROUPING = trained

GROUPING = untrained

Tests of Within-Subjects Contrasts[a]

Measure: MEASURE_1

Source	TIME	Type III Sum of Squares	df	Mean Square	F	Sig.
TIME	Level 2 vs. Level 1	1389.979	1	1389.979	15.457	.008
	Level 3 vs. Level 1	1371.720	1	1371.720	15.189	.008
	Level 4 vs. Level 1	1794.241	1	1794.241	26.662	.002
	Level 5 vs. Level 1	1526.184	1	1526.184	15.115	.008
	Level 6 vs. Level 1	750.272	1	750.272	7.553	.033
	Level 7 vs. Level 1	618.144	1	618.144	5.327	.060
	Level 8 vs. Level 1	750.272	1	750.272	6.451	.044
Error(TIME)	Level 2 vs. Level 1	539.539	6	89.923		
	Level 3 vs. Level 1	541.846	6	90.308		
	Level 4 vs. Level 1	403.774	6	67.296		
	Level 5 vs. Level 1	605.842	6	100.974		
	Level 6 vs. Level 1	595.976	6	99.329		
	Level 7 vs. Level 1	696.293	6	116.049		
	Level 8 vs. Level 1	697.843	6	116.307		

a. GROUPING = untrained

150°/second torque

GROUPING = trained

Tests of Within-Subjects Contrasts[a]

Measure: MEASURE_1

Source	TIME	Type III Sum of Squares	df	Mean Square	F	Sig.
TIME	Level 2 vs. Level 1	574.436	1	574.436	10.572	.014
	Level 3 vs. Level 1	1010.926	1	1010.926	20.583	.003
	Level 4 vs. Level 1	426.174	1	426.174	5.481	.052
	Level 5 vs. Level 1	351.258	1	351.258	4.479	.072
	Level 6 vs. Level 1	99.264	1	99.264	.954	.361
	Level 7 vs. Level 1	68.914	1	68.914	.578	.472
	Level 8 vs. Level 1	50.652	1	50.652	.488	.508
Error(TIME)	Level 2 vs. Level 1	380.365	7	54.338		
	Level 3 vs. Level 1	343.805	7	49.115		
	Level 4 vs. Level 1	544.250	7	77.750		
	Level 5 vs. Level 1	548.937	7	78.420		
	Level 6 vs. Level 1	728.443	7	104.063		
	Level 7 vs. Level 1	834.778	7	119.254		
	Level 8 vs. Level 1	727.179	7	103.883		

a. GROUPING = trained

GROUPING = untrained

Tests of Within-Subjects Contrasts[a]

Measure: MEASURE_1

Source	TIME	Type III Sum of Squares	df	Mean Square	F	Sig.
TIME	Level 2 vs. Level 1	1208.092	1	1208.092	22.358	.003
	Level 3 vs. Level 1	866.026	1	866.026	18.442	.005
	Level 4 vs. Level 1	1353.304	1	1353.304	15.758	.007
	Level 5 vs. Level 1	778.696	1	778.696	9.135	.023
	Level 6 vs. Level 1	866.248	1	866.248	11.895	.014
	Level 7 vs. Level 1	411.956	1	411.956	6.219	.047
	Level 8 vs. Level 1	381.841	1	381.841	3.702	.103
Error(TIME)	Level 2 vs. Level 1	324.197	6	54.033		
	Level 3 vs. Level 1	281.755	6	46.959		
	Level 4 vs. Level 1	515.286	6	85.881		
	Level 5 vs. Level 1	511.461	6	85.243		
	Level 6 vs. Level 1	436.960	6	72.827		
	Level 7 vs. Level 1	397.434	6	66.239		
	Level 8 vs. Level 1	618.827	6	103.138		

a. GROUPING = untrained

210°/second torque

GROUPING = trained

Tests of Within-Subjects Contrasts[a]

Measure: MEASURE_1

Source	TIME	Type III Sum of Squares	df	Mean Square	F	Sig.
TIME	Level 2 vs. Level 1	405.128	1	405.128	11.847	.011
	Level 3 vs. Level 1	781.508	1	781.508	26.281	.001
	Level 4 vs. Level 1	145.266	1	145.266	2.936	.130
	Level 5 vs. Level 1	107.385	1	107.385	1.588	.248
	Level 6 vs. Level 1	19.908	1	19.908	.181	.683
	Level 7 vs. Level 1	72.180	1	72.180	.885	.378
	Level 8 vs. Level 1	2.163	1	2.163	.019	.893
Error(TIME)	Level 2 vs. Level 1	239.370	7	34.196		
	Level 3 vs. Level 1	208.153	7	29.736		
	Level 4 vs. Level 1	346.298	7	49.471		
	Level 5 vs. Level 1	473.478	7	67.640		
	Level 6 vs. Level 1	770.154	7	110.022		
	Level 7 vs. Level 1	571.106	7	81.587		
	Level 8 vs. Level 1	785.562	7	112.223		

a. GROUPING = trained

GROUPING = untrained

Tests of Within-Subjects Contrasts[a]

Measure: MEASURE_1

Source	TIME	Type III Sum of Squares	df	Mean Square	F	Sig.
TIME	Level 2 vs. Level 1	907.986	1	907.986	17.955	.008
	Level 3 vs. Level 1	706.552	1	706.552	12.237	.017
	Level 4 vs. Level 1	594.612	1	594.612	11.935	.018
	Level 5 vs. Level 1	796.032	1	796.032	11.764	.019
	Level 6 vs. Level 1	796.032	1	796.032	7.144	.044
	Level 7 vs. Level 1	742.594	1	742.594	6.735	.049
	Level 8 vs. Level 1	504.533	1	504.533	2.903	.149
Error(TIME)	Level 2 vs. Level 1	252.845	5	50.569		
	Level 3 vs. Level 1	288.703	5	57.741		
	Level 4 vs. Level 1	249.101	5	49.820		
	Level 5 vs. Level 1	338.341	5	67.668		
	Level 6 vs. Level 1	557.150	5	111.430		
	Level 7 vs. Level 1	551.269	5	110.254		
	Level 8 vs. Level 1	869.091	5	173.818		

a. GROUPING = untrained

300°/second torque

GROUPING = trained

Tests of Within-Subjects Contrasts[a]

Measure: MEASURE_1

Source	TIME	Type III Sum of Squares	df	Mean Square	F	Sig.
TIME	Level 2 vs. Level 1	351.390	1	351.390	21.110	.003
	Level 3 vs. Level 1	632.612	1	632.612	45.599	.000
	Level 4 vs. Level 1	94.600	1	94.600	2.531	.156
	Level 5 vs. Level 1	223.450	1	223.450	11.936	.011
	Level 6 vs. Level 1	22.512	1	22.512	.282	.612
	Level 7 vs. Level 1	35.238	1	35.238	.580	.471
	Level 8 vs. Level 1	8.120	1	8.120	.076	.790
Error(TIME)	Level 2 vs. Level 1	116.519	7	16.646		
	Level 3 vs. Level 1	97.114	7	13.873		
	Level 4 vs. Level 1	261.593	7	37.370		
	Level 5 vs. Level 1	131.042	7	18.720		
	Level 6 vs. Level 1	559.371	7	79.910		
	Level 7 vs. Level 1	425.542	7	60.792		
	Level 8 vs. Level 1	743.408	7	106.201		

a. GROUPING = trained

GROUPING = untrained

Tests of Within-Subjects Contrasts[a]

Measure: MEASURE_1

Source	TIME	Type III Sum of Squares	df	Mean Square	F	Sig.
TIME	Level 2 vs. Level 1	630.800	1	630.800	11.134	.016
	Level 3 vs. Level 1	401.589	1	401.589	8.318	.028
	Level 4 vs. Level 1	696.006	1	696.006	19.122	.005
	Level 5 vs. Level 1	443.372	1	443.372	6.319	.046
	Level 6 vs. Level 1	580.580	1	580.580	6.535	.043
	Level 7 vs. Level 1	324.224	1	324.224	3.520	.110
	Level 8 vs. Level 1	306.241	1	306.241	2.951	.137
Error(TIME)	Level 2 vs. Level 1	339.932	6	56.655		
	Level 3 vs. Level 1	289.686	6	48.281		
	Level 4 vs. Level 1	218.386	6	36.398		
	Level 5 vs. Level 1	421.018	6	70.170		
	Level 6 vs. Level 1	533.009	6	88.835		
	Level 7 vs. Level 1	552.587	6	92.098		
	Level 8 vs. Level 1	622.562	6	103.760		

a. GROUPING = untrained

Extension SOR

GROUPING = trained

Tests of Within-Subjects Contrasts[a]

Measure: MEASURE_1

Source	TIME	Type III Sum of Squares	df	Mean Square	F	Sig.
TIME	Level 2 vs. Level 1	4656.125	1	4656.125	5.851	.046
	Level 3 vs. Level 1	4050.000	1	4050.000	5.044	.060
	Level 4 vs. Level 1	800.000	1	800.000	5.303	.055
	Level 5 vs. Level 1	180.500	1	180.500	5.458	.052
	Level 6 vs. Level 1	10.125	1	10.125	2.849	.135
Error(TIME)	Level 2 vs. Level 1	5570.875	7	795.839		
	Level 3 vs. Level 1	5620.000	7	802.857		
	Level 4 vs. Level 1	1056.000	7	150.857		
	Level 5 vs. Level 1	231.500	7	33.071		
	Level 6 vs. Level 1	24.875	7	3.554		

a. GROUPING = trained

GROUPING = untrained

Tests of Within-Subjects Contrasts[a]

Measure: MEASURE_1

Source	TIME	Type III Sum of Squares	df	Mean Square	F	Sig.
TIME	Level 2 vs. Level 1	2485.125	1	2485.125	15.102	.006
	Level 3 vs. Level 1	8192.000	1	8192.000	27.411	.001
	Level 4 vs. Level 1	5000.000	1	5000.000	9.744	.017
	Level 5 vs. Level 1	5408.000	1	5408.000	5.157	.057
	Level 6 vs. Level 1	3120.500	1	3120.500	3.353	.110
Error(TIME)	Level 2 vs. Level 1	1151.875	7	164.554		
	Level 3 vs. Level 1	2092.000	7	298.857		
	Level 4 vs. Level 1	3592.000	7	513.143		
	Level 5 vs. Level 1	7340.000	7	1048.571		
	Level 6 vs. Level 1	6515.500	7	930.786		

a. GROUPING = untrained

Flexion SOR

GROUPING = trained

Tests of Within-Subjects Contrasts[a]

Measure: MEASURE_1

Source	TIME	Type III Sum of Squares	df	Mean Square	F	Sig.
TIME	Level 2 vs. Level 1	496.125	1	496.125	8.885	.020
	Level 3 vs. Level 1	351.125	1	351.125	6.985	.033
	Level 4 vs. Level 1	91.125	1	91.125	6.141	.042
	Level 5 vs. Level 1	12.500	1	12.500	5.000	.060
	Level 6 vs. Level 1	15.125	1	15.125	3.798	.092
Error(TIME)	Level 2 vs. Level 1	390.875	7	55.839		
	Level 3 vs. Level 1	351.875	7	50.268		
	Level 4 vs. Level 1	103.875	7	14.839		
	Level 5 vs. Level 1	17.500	7	2.500		
	Level 6 vs. Level 1	27.875	7	3.982		

a. GROUPING = trained

GROUPING = untrained

Tests of Within-Subjects Contrasts[a]

Measure: MEASURE_1

Source	TIME	Type III Sum of Squares	df	Mean Square	F	Sig.
TIME	Level 2 vs. Level 1	666.125	1	666.125	6.769	.035
	Level 3 vs. Level 1	1035.125	1	1035.125	6.280	.041
	Level 4 vs. Level 1	1711.125	1	1711.125	3.945	.087
	Level 5 vs. Level 1	2178.000	1	2178.000	2.661	.147
	Level 6 vs. Level 1	435.125	1	435.125	2.009	.199
Error(TIME)	Level 2 vs. Level 1	688.875	7	98.411		
	Level 3 vs. Level 1	1153.875	7	164.839		
	Level 4 vs. Level 1	3035.875	7	433.696		
	Level 5 vs. Level 1	5730.000	7	818.571		
	Level 6 vs. Level 1	1515.875	7	216.554		

a. GROUPING = untrained

Upper arm SOR

GROUPING = trained

Tests of Within-Subjects Contrasts[a]

Measure: MEASURE_1

Source	TIME	Type III Sum of Squares	df	Mean Square	F	Sig.
TIME	Level 2 vs. Level 1	55611.125	1	55611.125	29.922	.001
	Level 3 vs. Level 1	61425.125	1	61425.125	39.976	.000
	Level 4 vs. Level 1	36046.125	1	36046.125	14.359	.007
	Level 5 vs. Level 1	7381.125	1	7381.125	4.785	.065
	Level 6 vs. Level 1	1568.000	1	1568.000	5.600	.050
Error(TIME)	Level 2 vs. Level 1	13009.875	7	1858.554		
	Level 3 vs. Level 1	10755.875	7	1536.554		
	Level 4 vs. Level 1	17572.875	7	2510.411		
	Level 5 vs. Level 1	10797.875	7	1542.554		
	Level 6 vs. Level 1	1960.000	7	280.000		

a. GROUPING = trained

GROUPING = untrained

Tests of Within-Subjects Contrasts[a]

Measure: MEASURE_1

Source	TIME	Type III Sum of Squares	df	Mean Square	F	Sig.
TIME	Level 2 vs. Level 1	30504.500	1	30504.500	13.886	.007
	Level 3 vs. Level 1	67161.125	1	67161.125	17.415	.004
	Level 4 vs. Level 1	65884.500	1	65884.500	12.152	.010
	Level 5 vs. Level 1	45300.500	1	45300.500	7.400	.030
	Level 6 vs. Level 1	24976.125	1	24976.125	7.416	.030
Error(TIME)	Level 2 vs. Level 1	15377.500	7	2196.786		
	Level 3 vs. Level 1	26995.875	7	3856.554		
	Level 4 vs. Level 1	37951.500	7	5421.643		
	Level 5 vs. Level 1	42849.500	7	6121.357		
	Level 6 vs. Level 1	23574.875	7	3367.839		

a. GROUPING = untrained

Forearm SOR

GROUPING = trained

Tests of Within-Subjects Contrasts[a]

Measure: MEASURE_1

Source	TIME	Type III Sum of Squares	df	Mean Square	F	Sig.
TIME	Level 2 vs. Level 1	9730.125	1	9730.125	17.024	.004
	Level 3 vs. Level 1	4656.125	1	4656.125	7.547	.029
	Level 4 vs. Level 1	1012.500	1	1012.500	8.865	.021
	Level 5 vs. Level 1	190.125	1	190.125	5.305	.055
	Level 6 vs. Level 1	50.000	1	50.000	2.134	.187
Error(TIME)	Level 2 vs. Level 1	4000.875	7	571.554		
	Level 3 vs. Level 1	4318.875	7	616.982		
	Level 4 vs. Level 1	799.500	7	114.214		
	Level 5 vs. Level 1	250.875	7	35.839		
	Level 6 vs. Level 1	164.000	7	23.429		

a. GROUPING = trained

GROUPING = untrained

Tests of Within-Subjects Contrasts[a]

Measure: MEASURE_1

Source	TIME	Type III Sum of Squares	df	Mean Square	F	Sig.
TIME	Level 2 vs. Level 1	2812.500	1	2812.500	8.057	.025
	Level 3 vs. Level 1	3444.500	1	3444.500	14.425	.007
	Level 4 vs. Level 1	5100.500	1	5100.500	18.258	.004
	Level 5 vs. Level 1	3570.125	1	3570.125	6.200	.042
	Level 6 vs. Level 1	1740.500	1	1740.500	3.817	.092
Error(TIME)	Level 2 vs. Level 1	2443.500	7	349.071		
	Level 3 vs. Level 1	1671.500	7	238.786		
	Level 4 vs. Level 1	1955.500	7	279.357		
	Level 5 vs. Level 1	4030.875	7	575.839		
	Level 6 vs. Level 1	3191.500	7	455.929		

a. GROUPING = untrained

CIR

GROUPING = trained

Tests of Within-Subjects Contrasts[a]

Measure: MEASURE_1

Source	TIME	Type III Sum of Squares	df	Mean Square	F	Sig.
TIME	Level 2 vs. Level 1	.401	1	.401	5.324	.054
	Level 3 vs. Level 1	.270	1	.270	1.992	.201
	Level 4 vs. Level 1	2.322	1	2.322	10.730	.014
	Level 5 vs. Level 1	1.163	1	1.163	2.910	.132
	Level 6 vs. Level 1	.332	1	.332	.708	.428
	Level 7 vs. Level 1	.340	1	.340	1.872	.214
	Level 8 vs. Level 1	.865	1	.865	5.140	.058
Error(TIME)	Level 2 vs. Level 1	.527	7	7.523E-02		
	Level 3 vs. Level 1	.949	7	.136		
	Level 4 vs. Level 1	1.515	7	.216		
	Level 5 vs. Level 1	2.797	7	.400		
	Level 6 vs. Level 1	3.282	7	.469		
	Level 7 vs. Level 1	1.273	7	.182		
	Level 8 vs. Level 1	1.177	7	.168		

a. GROUPING = trained

GROUPING = untrained

Tests of Within-Subjects Contrasts[a]

Measure: MEASURE_1

Source	TIME	Type III Sum of Squares	df	Mean Square	F	Sig.
TIME	Level 2 vs. Level 1	2.122	1	2.122	6.740	.036
	Level 3 vs. Level 1	1.378	1	1.378	5.916	.045
	Level 4 vs. Level 1	6.444	1	6.444	52.115	.000
	Level 5 vs. Level 1	6.882	1	6.882	27.738	.001
	Level 6 vs. Level 1	11.022	1	11.022	13.942	.007
	Level 7 vs. Level 1	13.992	1	13.992	8.269	.024
	Level 8 vs. Level 1	15.346	1	15.346	9.897	.016
Error(TIME)	Level 2 vs. Level 1	2.204	7	.315		
	Level 3 vs. Level 1	1.630	7	.233		
	Level 4 vs. Level 1	.866	7	.124		
	Level 5 vs. Level 1	1.737	7	.248		
	Level 6 vs. Level 1	5.534	7	.791		
	Level 7 vs. Level 1	11.845	7	1.692		
	Level 8 vs. Level 1	10.854	7	1.551		

a. GROUPING = untrained

Change in FANG

GROUPING = trained

Tests of Within-Subjects Contrasts[a]

Measure: MEASURE_1

Source	TIME	Type III Sum of Squares	df	Mean Square	F	Sig.
TIME	Level 2 vs. Level 1	603.781	1	603.781	34.370	.001
	Level 3 vs. Level 1	406.125	1	406.125	27.634	.001
	Level 4 vs. Level 1	124.031	1	124.031	13.734	.008
	Level 5 vs. Level 1	57.781	1	57.781	20.255	.003
	Level 6 vs. Level 1	8.000	1	8.000	3.111	.121
	Level 7 vs. Level 1	.281	1	.281	.045	.838
	Level 8 vs. Level 1	1.531	1	1.531	.240	.639
Error(TIME)	Level 2 vs. Level 1	122.969	7	17.567		
	Level 3 vs. Level 1	102.875	7	14.696		
	Level 4 vs. Level 1	63.219	7	9.031		
	Level 5 vs. Level 1	19.969	7	2.853		
	Level 6 vs. Level 1	18.000	7	2.571		
	Level 7 vs. Level 1	43.469	7	6.210		
	Level 8 vs. Level 1	44.719	7	6.388		

a. GROUPING = trained

GROUPING = untrained

Tests of Within-Subjects Contrasts[a]

Measure: MEASURE_1

Source	TIME	Type III Sum of Squares	df	Mean Square	F	Sig.
TIME	Level 2 vs. Level 1	693.781	1	693.781	51.958	.000
	Level 3 vs. Level 1	242.000	1	242.000	11.888	.011
	Level 4 vs. Level 1	371.281	1	371.281	11.896	.011
	Level 5 vs. Level 1	569.531	1	569.531	27.934	.001
	Level 6 vs. Level 1	512.000	1	512.000	14.629	.007
	Level 7 vs. Level 1	435.125	1	435.125	7.675	.028
	Level 8 vs. Level 1	331.531	1	331.531	6.713	.036
Error(TIME)	Level 2 vs. Level 1	93.469	7	13.353		
	Level 3 vs. Level 1	142.500	7	20.357		
	Level 4 vs. Level 1	218.469	7	31.210		
	Level 5 vs. Level 1	142.719	7	20.388		
	Level 6 vs. Level 1	245.000	7	35.000		
	Level 7 vs. Level 1	396.875	7	56.696		
	Level 8 vs. Level 1	345.719	7	49.388		

a. GROUPING = untrained

Change in RANG

GROUPING = trained

Tests of Within-Subjects Contrasts[a]

Measure: MEASURE_1

Source	TIME	Type III Sum of Squares	df	Mean Square	F	Sig.
TIME	Level 2 vs. Level 1	36.125	1	36.125	3.186	.117
	Level 3 vs. Level 1	42.781	1	42.781	4.718	.066
	Level 4 vs. Level 1	78.125	1	78.125	6.406	.039
	Level 5 vs. Level 1	15.125	1	15.125	1.829	.218
	Level 6 vs. Level 1	72.000	1	72.000	4.870	.063
	Level 7 vs. Level 1	10.125	1	10.125	1.340	.285
	Level 8 vs. Level 1	7.031	1	7.031	2.778	.140
Error(TIME)	Level 2 vs. Level 1	79.375	7	11.339		
	Level 3 vs. Level 1	63.469	7	9.067		
	Level 4 vs. Level 1	85.375	7	12.196		
	Level 5 vs. Level 1	57.875	7	8.268		
	Level 6 vs. Level 1	103.500	7	14.786		
	Level 7 vs. Level 1	52.875	7	7.554		
	Level 8 vs. Level 1	17.719	7	2.531		

a. GROUPING = trained

GROUPING = untrained

Tests of Within-Subjects Contrasts[a]

Measure: MEASURE_1

Source	TIME	Type III Sum of Squares	df	Mean Square	F	Sig.
TIME	Level 2 vs. Level 1	258.781	1	258.781	3.192	.117
	Level 3 vs. Level 1	40.500	1	40.500	2.372	.167
	Level 4 vs. Level 1	338.000	1	338.000	8.763	.021
	Level 5 vs. Level 1	190.125	1	190.125	6.039	.044
	Level 6 vs. Level 1	1058.000	1	1058.000	4.050	.084
	Level 7 vs. Level 1	1212.781	1	1212.781	2.235	.179
	Level 8 vs. Level 1	731.531	1	731.531	1.614	.245
Error(TIME)	Level 2 vs. Level 1	567.469	7	81.067		
	Level 3 vs. Level 1	119.500	7	17.071		
	Level 4 vs. Level 1	270.000	7	38.571		
	Level 5 vs. Level 1	220.375	7	31.482		
	Level 6 vs. Level 1	1828.500	7	261.214		
	Level 7 vs. Level 1	3797.969	7	542.567		
	Level 8 vs. Level 1	3173.219	7	453.317		

a. GROUPING = untrained

Plasma CK concentration

GROUPING = trained

Tests of Within-Subjects Contrasts[a]

Measure: MEASURE_1

Source	TIME	Type III Sum of Squares	df	Mean Square	F	Sig.
TIME	Level 2 vs. Level 1	138603.571	1	138603.571	2.358	.176
	Level 3 vs. Level 1	2800.000	1	2800.000	.039	.850
	Level 4 vs. Level 1	574862.286	1	574862.286	1.518	.264
	Level 5 vs. Level 1	732242.286	1	732242.286	1.169	.321
	Level 6 vs. Level 1	1300327.000	1	1300327.000	1.381	.285
Error(TIME)	Level 2 vs. Level 1	352669.429	6	58778.238		
	Level 3 vs. Level 1	430134.000	6	71689.000		
	Level 4 vs. Level 1	2271637.714	6	378606.286		
	Level 5 vs. Level 1	3757791.714	6	626298.619		
	Level 6 vs. Level 1	5650824.000	6	941804.000		

a. GROUPING = trained

GROUPING = untrained

Tests of Within-Subjects Contrasts[a]

Measure: MEASURE_1

Source	TIME	Type III Sum of Squares	df	Mean Square	F	Sig.
TIME	Level 2 vs. Level 1	936190.861	1	936190.861	2.705	.144
	Level 3 vs. Level 1	5629857.901	1	5629857.901	1.221	.306
	Level 4 vs. Level 1	18509657.5	1	18509657.46	1.619	.244
	Level 5 vs. Level 1	45504369.0	1	45504369.01	3.477	.104
	Level 6 vs. Level 1	62920079.3	1	62920079.31	4.114	.082
Error(TIME)	Level 2 vs. Level 1	2422865.829	7	346123.690		
	Level 3 vs. Level 1	32279611.7	7	4611373.101		
	Level 4 vs. Level 1	80024635.0	7	11432090.72		
	Level 5 vs. Level 1	91613139.3	7	13087591.33		
	Level 6 vs. Level 1	107057091	7	15293870.14		

a. GROUPING = untrained

Appendix F

One-way repeated measures ANOVA's with repeated measures

Isometric 90° torque

GROUPING = trained

Tests of Within-Subjects Contrasts[a]

Measure: MEASURE_1

Source	TIME	Type III Sum of Squares	df	Mean Square	F	Sig.
TIME	Level 1 vs. Level 2	2829.776	1	2829.776	26.864	.001
	Level 2 vs. Level 3	42.504	1	42.504	.763	.411
	Level 3 vs. Level 4	620.753	1	620.753	5.787	.047
	Level 4 vs. Level 5	3.906	1	3.906	.422	.537
	Level 5 vs. Level 6	238.711	1	238.711	10.898	.013
	Level 6 vs. Level 7	59.078	1	59.078	3.538	.102
	Level 7 vs. Level 8	.994	1	.994	.025	.880
Error(TIME)	Level 1 vs. Level 2	737.351	7	105.336		
	Level 2 vs. Level 3	389.828	7	55.690		
	Level 3 vs. Level 4	750.925	7	107.275		
	Level 4 vs. Level 5	64.840	7	9.263		
	Level 5 vs. Level 6	153.330	7	21.904		
	Level 6 vs. Level 7	116.904	7	16.701		
	Level 7 vs. Level 8	282.591	7	40.370		

a. GROUPING = trained

GROUPING = untrained

Tests of Within-Subjects Contrasts[a]

Measure: MEASURE_1

Source	TIME	Type III Sum of Squares	df	Mean Square	F	Sig.
TIME	Level 1 vs. Level 2	2805.844	1	2805.844	16.219	.010
	Level 2 vs. Level 3	5.042E-02	1	5.042E-02	.003	.958
	Level 3 vs. Level 4	10.218	1	10.218	1.526	.272
	Level 4 vs. Level 5	11.760	1	11.760	.982	.367
	Level 5 vs. Level 6	63.896	1	63.896	8.742	.032
	Level 6 vs. Level 7	169.283	1	169.283	5.619	.064
	Level 7 vs. Level 8	25.256	1	25.256	8.542	.033
Error(TIME)	Level 1 vs. Level 2	864.963	5	172.993		
	Level 2 vs. Level 3	82.180	5	16.436		
	Level 3 vs. Level 4	33.485	5	6.697		
	Level 4 vs. Level 5	59.864	5	11.973		
	Level 5 vs. Level 6	36.546	5	7.309		
	Level 6 vs. Level 7	150.635	5	30.127		
	Level 7 vs. Level 8	14.784	5	2.957		

a. GROUPING = untrained

Isometric 150° torque

GROUPING = trained

Tests of Within-Subjects Contrasts[a]

Measure: MEASURE_1

Source	TIME	Type III Sum of Squares	df	Mean Square	F	Sig.
TIME	Level 1 vs. Level 2	1225.620	1	1225.620	43.095	.000
	Level 2 vs. Level 3	117.888	1	117.888	2.992	.127
	Level 3 vs. Level 4	225.781	1	225.781	4.796	.065
	Level 4 vs. Level 5	28.501	1	28.501	1.647	.240
	Level 5 vs. Level 6	17.111	1	17.111	1.164	.316
	Level 6 vs. Level 7	72.601	1	72.601	3.745	.094
	Level 7 vs. Level 8	1.921	1	1.921	.050	.830
Error(TIME)	Level 1 vs. Level 2	199.079	7	28.440		
	Level 2 vs. Level 3	275.794	7	39.399		
	Level 3 vs. Level 4	329.516	7	47.074		
	Level 4 vs. Level 5	121.143	7	17.306		
	Level 5 vs. Level 6	102.876	7	14.697		
	Level 6 vs. Level 7	135.720	7	19.389		
	Level 7 vs. Level 8	271.270	7	38.753		

a. GROUPING = trained

GROUPING = untrained

Tests of Within-Subjects Contrasts[a]

Measure: MEASURE_1

Source	TIME	Type III Sum of Squares	df	Mean Square	F	Sig.
TIME	Level 1 vs. Level 2	1765.078	1	1765.078	13.102	.015
	Level 2 vs. Level 3	5.227E-02	1	5.227E-02	.003	.959
	Level 3 vs. Level 4	5.042E-02	1	5.042E-02	.003	.959
	Level 4 vs. Level 5	.470	1	.470	.042	.846
	Level 5 vs. Level 6	46.928	1	46.928	2.345	.186
	Level 6 vs. Level 7	67.536	1	67.536	1.637	.257
	Level 7 vs. Level 8	25.215	1	25.215	1.355	.297
Error(TIME)	Level 1 vs. Level 2	673.603	5	134.721		
	Level 2 vs. Level 3	90.366	5	18.073		
	Level 3 vs. Level 4	87.142	5	17.428		
	Level 4 vs. Level 5	56.123	5	11.225		
	Level 5 vs. Level 6	100.050	5	20.010		
	Level 6 vs. Level 7	206.316	5	41.263		
	Level 7 vs. Level 8	93.035	5	18.607		

a. GROUPING = untrained

30°/second torque

GROUPING = trained

Tests of Within-Subjects Contrasts[a]

Measure: MEASURE_1

Source	TIME	Type III Sum of Squares	df	Mean Square	F	Sig.
TIME	Level 1 vs. Level 2	811.038	1	811.038	12.614	.009
	Level 2 vs. Level 3	54.080	1	54.080	2.651	.147
	Level 3 vs. Level 4	158.064	1	158.064	2.711	.144
	Level 4 vs. Level 5	7.980	1	7.980	2.621	.150
	Level 5 vs. Level 6	30.070	1	30.070	3.409	.107
	Level 6 vs. Level 7	78.063	1	78.063	4.988	.061
	Level 7 vs. Level 8	6.480	1	6.480	.629	.454
Error(TIME)	Level 1 vs. Level 2	450.093	7	64.299		
	Level 2 vs. Level 3	142.787	7	20.398		
	Level 3 vs. Level 4	408.202	7	58.315		
	Level 4 vs. Level 5	21.315	7	3.045		
	Level 5 vs. Level 6	61.744	7	8.821		
	Level 6 vs. Level 7	109.550	7	15.650		
	Level 7 vs. Level 8	72.066	7	10.295		

a. GROUPING = trained

GROUPING = untrained

Tests of Within-Subjects Contra

Measure: MEASURE_1

Source	TIME	Type III Sum of Squares	df	Mean Square	F	Sig.
TIME	Level 1 vs. Level 2	1753.173	1	1753.173	21.834	.003
	Level 2 vs. Level 3	1.594	1	1.594	.062	.812
	Level 3 vs. Level 4	.000	1	.000	.000	1.000
	Level 4 vs. Level 5	10.888	1	10.888	3.237	.122
	Level 5 vs. Level 6	74.458	1	74.458	21.189	.004
	Level 6 vs. Level 7	6.432	1	6.432	.290	.610
	Level 7 vs. Level 8	.577	1	.577	.020	.892
Error(TIME)	Level 1 vs. Level 2	481.775	6	80.296		
	Level 2 vs. Level 3	155.448	6	25.908		
	Level 3 vs. Level 4	55.851	6	9.309		
	Level 4 vs. Level 5	20.181	6	3.363		
	Level 5 vs. Level 6	21.084	6	3.514		
	Level 6 vs. Level 7	133.237	6	22.206		
	Level 7 vs. Level 8	171.794	6	28.632		

a. GROUPING = untrained

90°/second torque

GROUPING = trained

Tests of Within-Subjects Contrasts[a]

Measure: MEASURE_1

Source	TIME	Type III Sum of Squares	df	Mean Square	F	Sig.
TIME	Level 1 vs. Level 2	826.008	1	826.008	11.343	.012
	Level 2 vs. Level 3	129.203	1	129.203	11.723	.011
	Level 3 vs. Level 4	245.090	1	245.090	5.249	.056
	Level 4 vs. Level 5	24.922	1	24.922	2.305	.173
	Level 5 vs. Level 6	94.531	1	94.531	7.535	.029
	Level 6 vs. Level 7	8.100	1	8.100	.542	.485
	Level 7 vs. Level 8	65.151	1	65.151	5.973	.044
Error(TIME)	Level 1 vs. Level 2	509.735	7	72.819		
	Level 2 vs. Level 3	77.147	7	11.021		
	Level 3 vs. Level 4	326.851	7	46.693		
	Level 4 vs. Level 5	75.679	7	10.811		
	Level 5 vs. Level 6	87.823	7	12.546		
	Level 6 vs. Level 7	104.581	7	14.940		
	Level 7 vs. Level 8	76.354	7	10.908		

a. GROUPING = trained

GROUPING = untrained

Tests of Within-Subjects Contrasts[a]

Measure: MEASURE_1

Source	TIME	Type III Sum of Squares	df	Mean Square	F	Sig.
TIME	Level 1 vs. Level 2	1389.979	1	1389.979	15.457	.008
	Level 2 vs. Level 3	6.036E-02	1	6.036E-02	.006	.940
	Level 3 vs. Level 4	28.321	1	28.321	1.449	.274
	Level 4 vs. Level 5	10.838	1	10.838	1.406	.281
	Level 5 vs. Level 6	136.313	1	136.313	21.241	.004
	Level 6 vs. Level 7	6.394	1	6.394	1.383	.284
	Level 7 vs. Level 8	6.394	1	6.394	.449	.528
Error(TIME)	Level 1 vs. Level 2	539.539	6	89.923		
	Level 2 vs. Level 3	57.995	6	9.666		
	Level 3 vs. Level 4	117.264	6	19.544		
	Level 4 vs. Level 5	46.240	6	7.707		
	Level 5 vs. Level 6	38.504	6	6.417		
	Level 6 vs. Level 7	27.736	6	4.623		
	Level 7 vs. Level 8	85.397	6	14.233		

a. GROUPING = untrained

150°/second torque

GROUPING = trained

Tests of Within-Subjects Contrasts[a]

Measure: MEASURE_1

Source	TIME	Type III Sum of Squares	df	Mean Square	F	Sig.
TIME	Level 1 vs. Level 2	574.436	1	574.436	10.572	.014
	Level 2 vs. Level 3	61.272	1	61.272	4.889	.063
	Level 3 vs. Level 4	124.346	1	124.346	2.099	.191
	Level 4 vs. Level 5	3.618	1	3.618	.376	.559
	Level 5 vs. Level 6	77.066	1	77.066	5.989	.044
	Level 6 vs. Level 7	2.761	1	2.761	.212	.659
	Level 7 vs. Level 8	1.403	1	1.403	.086	.777
Error(TIME)	Level 1 vs. Level 2	380.365	7	54.338		
	Level 2 vs. Level 3	87.730	7	12.533		
	Level 3 vs. Level 4	414.650	7	59.236		
	Level 4 vs. Level 5	67.429	7	9.633		
	Level 5 vs. Level 6	90.079	7	12.868		
	Level 6 vs. Level 7	91.300	7	13.043		
	Level 7 vs. Level 8	113.523	7	16.218		

a. GROUPING = trained

GROUPING = untrained

Tests of Within-Subjects Contrasts[a]

Measure: MEASURE_1

Source	TIME	Type III Sum of Squares	df	Mean Square	F	Sig.
TIME	Level 1 vs. Level 2	1208.092	1	1208.092	22.358	.003
	Level 2 vs. Level 3	28.401	1	28.401	5.118	.064
	Level 3 vs. Level 4	54.154	1	54.154	2.384	.174
	Level 4 vs. Level 5	78.893	1	78.893	11.443	.015
	Level 5 vs. Level 6	2.332	1	2.332	.128	.733
	Level 6 vs. Level 7	83.456	1	83.456	6.661	.042
	Level 7 vs. Level 8	.571	1	.571	.033	.861
Error(TIME)	Level 1 vs. Level 2	324.197	6	54.033		
	Level 2 vs. Level 3	33.299	6	5.550		
	Level 3 vs. Level 4	136.280	6	22.713		
	Level 4 vs. Level 5	41.366	6	6.894		
	Level 5 vs. Level 6	109.358	6	18.226		
	Level 6 vs. Level 7	75.174	6	12.529		
	Level 7 vs. Level 8	103.285	6	17.214		

a. GROUPING = untrained

210°/second torque

GROUPING = trained

Tests of Within-Subjects Contrasts[a]

Measure: MEASURE_1

Source	TIME	Type III Sum of Squares	df	Mean Square	F	Sig.
TIME	Level 1 vs. Level 2	405.128	1	405.128	11.847	.011
	Level 2 vs. Level 3	61.272	1	61.272	5.922	.045
	Level 3 vs. Level 4	252.900	1	252.900	9.149	.019
	Level 4 vs. Level 5	2.856	1	2.856	.338	.579
	Level 5 vs. Level 6	34.820	1	34.820	1.452	.267
	Level 6 vs. Level 7	16.274	1	16.274	.893	.376
	Level 7 vs. Level 8	99.335	1	99.335	4.226	.079
Error(TIME)	Level 1 vs. Level 2	239.370	7	34.196		
	Level 2 vs. Level 3	72.426	7	10.347		
	Level 3 vs. Level 4	193.502	7	27.643		
	Level 4 vs. Level 5	59.080	7	8.440		
	Level 5 vs. Level 6	167.913	7	23.988		
	Level 6 vs. Level 7	127.543	7	18.220		
	Level 7 vs. Level 8	164.526	7	23.504		

a. GROUPING = trained

GROUPING = untrained

Tests of Within-Subjects Contrasts[a]

Measure: MEASURE_1

Source	TIME	Type III Sum of Squares	df	Mean Square	F	Sig.
TIME	Level 1 vs. Level 2	907.986	1	907.986	17.955	.008
	Level 2 vs. Level 3	12.615	1	12.615	.421	.545
	Level 3 vs. Level 4	4.824	1	4.824	.481	.519
	Level 4 vs. Level 5	14.664	1	14.664	.777	.418
	Level 5 vs. Level 6	.000	1	.000	.000	1.000
	Level 6 vs. Level 7	.928	1	.928	.084	.784
	Level 7 vs. Level 8	22.932	1	22.932	1.292	.307
Error(TIME)	Level 1 vs. Level 2	252.845	5	50.569		
	Level 2 vs. Level 3	149.787	5	29.957		
	Level 3 vs. Level 4	50.116	5	10.023		
	Level 4 vs. Level 5	94.345	5	18.869		
	Level 5 vs. Level 6	84.729	5	16.946		
	Level 6 vs. Level 7	55.474	5	11.095		
	Level 7 vs. Level 8	88.772	5	17.754		

a. GROUPING = untrained

300°/second torque

GROUPING = trained

Tests of Within-Subjects Contrasts[a]

Measure: MEASURE_1

Source	TIME	Type III Sum of Squares	df	Mean Square	F	Sig.
TIME	Level 1 vs. Level 2	351.390	1	351.390	21.110	.003
	Level 2 vs. Level 3	41.042	1	41.042	2.616	.150
	Level 3 vs. Level 4	237.947	1	237.947	7.497	.029
	Level 4 vs. Level 5	27.269	1	27.269	1.797	.222
	Level 5 vs. Level 6	104.112	1	104.112	2.943	.130
	Level 6 vs. Level 7	1.420	1	1.420	.133	.726
	Level 7 vs. Level 8	77.190	1	77.190	2.181	.183
Error(TIME)	Level 1 vs. Level 2	116.519	7	16.646		
	Level 2 vs. Level 3	109.823	7	15.689		
	Level 3 vs. Level 4	222.164	7	31.738		
	Level 4 vs. Level 5	106.223	7	15.175		
	Level 5 vs. Level 6	247.659	7	35.380		
	Level 6 vs. Level 7	74.632	7	10.662		
	Level 7 vs. Level 8	247.728	7	35.390		

a. GROUPING = trained

GROUPING = untrained

Tests of Within-Subjects Contrasts[a]

Measure: MEASURE_1

Source	TIME	Type III Sum of Squares	df	Mean Square	F	Sig.
TIME	Level 1 vs. Level 2	630.800	1	630.800	11.134	.016
	Level 2 vs. Level 3	25.766	1	25.766	7.021	.038
	Level 3 vs. Level 4	40.224	1	40.224	8.681	.026
	Level 4 vs. Level 5	28.361	1	28.361	2.658	.154
	Level 5 vs. Level 6	9.235	1	9.235	1.675	.243
	Level 6 vs. Level 7	37.076	1	37.076	16.599	.007
	Level 7 vs. Level 8	.257	1	.257	.034	.859
Error(TIME)	Level 1 vs. Level 2	339.932	6	56.655		
	Level 2 vs. Level 3	22.018	6	3.670		
	Level 3 vs. Level 4	27.801	6	4.634		
	Level 4 vs. Level 5	64.026	6	10.671		
	Level 5 vs. Level 6	33.069	6	5.512		
	Level 6 vs. Level 7	13.402	6	2.234		
	Level 7 vs. Level 8	44.781	6	7.464		

a. GROUPING = untrained

Extension SOR

GROUPING = trained

Tests of Within-Subjects Contrasts[a]

Measure: MEASURE_1

Source	TIME	Type III Sum of Squares	df	Mean Square	F	Sig.
TIME	Level 1 vs. Level 2	4656.125	1	4656.125	5.851	.046
	Level 2 vs. Level 3	21.125	1	21.125	.226	.649
	Level 3 vs. Level 4	1250.000	1	1250.000	3.489	.104
	Level 4 vs. Level 5	220.500	1	220.500	1.274	.296
	Level 5 vs. Level 6	105.125	1	105.125	5.666	.049
Error(TIME)	Level 1 vs. Level 2	5570.875	7	795.839		
	Level 2 vs. Level 3	653.875	7	93.411		
	Level 3 vs. Level 4	2508.000	7	358.286		
	Level 4 vs. Level 5	1211.500	7	173.071		
	Level 5 vs. Level 6	129.875	7	18.554		

a. GROUPING = trained

GROUPING = untrained

Tests of Within-Subjects Contrasts[a]

Measure: MEASURE_1

Source	TIME	Type III Sum of Squares	df	Mean Square	F	Sig.
TIME	Level 1 vs. Level 2	2485.125	1	2485.125	15.102	.006
	Level 2 vs. Level 3	1653.125	1	1653.125	4.052	.084
	Level 3 vs. Level 4	392.000	1	392.000	1.943	.206
	Level 4 vs. Level 5	8.000	1	8.000	.033	.860
	Level 5 vs. Level 6	312.500	1	312.500	3.855	.090
Error(TIME)	Level 1 vs. Level 2	1151.875	7	164.554		
	Level 2 vs. Level 3	2855.875	7	407.982		
	Level 3 vs. Level 4	1412.000	7	201.714		
	Level 4 vs. Level 5	1684.000	7	240.571		
	Level 5 vs. Level 6	567.500	7	81.071		

a. GROUPING = untrained

Flexion SOR

GROUPING = trained

Tests of Within-Subjects Contrasts[a]

Measure: MEASURE_1

Source	TIME	Type III Sum of Squares	df	Mean Square	F	Sig.
TIME	Level 1 vs. Level 2	496.125	1	496.125	8.885	.020
	Level 2 vs. Level 3	12.500	1	12.500	.266	.622
	Level 3 vs. Level 4	84.500	1	84.500	3.057	.124
	Level 4 vs. Level 5	36.125	1	36.125	5.898	.046
	Level 5 vs. Level 6	.125	1	.125	.099	.763
Error(TIME)	Level 1 vs. Level 2	390.875	7	55.839		
	Level 2 vs. Level 3	329.500	7	47.071		
	Level 3 vs. Level 4	193.500	7	27.643		
	Level 4 vs. Level 5	42.875	7	6.125		
	Level 5 vs. Level 6	8.875	7	1.268		

a. GROUPING = trained

GROUPING = untrained

Tests of Within-Subjects Contrasts[a]

Measure: MEASURE_1

Source	TIME	Type III Sum of Squares	df	Mean Square	F	Sig.
TIME	Level 1 vs. Level 2	666.125	1	666.125	6.769	.035
	Level 2 vs. Level 3	40.500	1	40.500	.825	.394
	Level 3 vs. Level 4	84.500	1	84.500	.591	.467
	Level 4 vs. Level 5	28.125	1	28.125	.122	.737
	Level 5 vs. Level 6	666.125	1	666.125	3.296	.112
Error(TIME)	Level 1 vs. Level 2	688.875	7	98.411		
	Level 2 vs. Level 3	343.500	7	49.071		
	Level 3 vs. Level 4	1001.500	7	143.071		
	Level 4 vs. Level 5	1610.875	7	230.125		
	Level 5 vs. Level 6	1414.875	7	202.125		

a. GROUPING = untrained

Upper arm SOR

GROUPING = trained

Tests of Within-Subjects Contrasts[a]

Measure: MEASURE_1

Source	TIME	Type III Sum of Squares	df	Mean Square	F	Sig.
TIME	Level 1 vs. Level 2	55611.125	1	55611.125	29.922	.001
	Level 2 vs. Level 3	144.500	1	144.500	.102	.758
	Level 3 vs. Level 4	3362.000	1	3362.000	3.494	.104
	Level 4 vs. Level 5	10804.500	1	10804.500	19.546	.003
	Level 5 vs. Level 6	2145.125	1	2145.125	3.132	.120
Error(TIME)	Level 1 vs. Level 2	13009.875	7	1858.554		
	Level 2 vs. Level 3	9873.500	7	1410.500		
	Level 3 vs. Level 4	6736.000	7	962.286		
	Level 4 vs. Level 5	3869.500	7	552.786		
	Level 5 vs. Level 6	4793.875	7	684.839		

a. GROUPING = trained

GROUPING = untrained

Tests of Within-Subjects Contrasts[a]

Measure: MEASURE_1

Source	TIME	Type III Sum of Squares	df	Mean Square	F	Sig.
TIME	Level 1 vs. Level 2	30504.500	1	30504.500	13.886	.007
	Level 2 vs. Level 3	7140.125	1	7140.125	5.687	.049
	Level 3 vs. Level 4	6.125	1	6.125	.003	.955
	Level 4 vs. Level 5	1922.000	1	1922.000	.919	.370
	Level 5 vs. Level 6	3003.125	1	3003.125	4.789	.065
Error(TIME)	Level 1 vs. Level 2	15377.500	7	2196.786		
	Level 2 vs. Level 3	8788.875	7	1255.554		
	Level 3 vs. Level 4	12634.875	7	1804.982		
	Level 4 vs. Level 5	14634.000	7	2090.571		
	Level 5 vs. Level 6	4389.875	7	627.125		

a. GROUPING = untrained

Forearm SOR

GROUPING = trained

Tests of Within-Subjects Contrasts[a]

Measure: MEASURE_1

Source	TIME	Type III Sum of Squares	df	Mean Square	F	Sig.
TIME	Level 1 vs. Level 2	9730.125	1	9730.125	17.024	.004
	Level 2 vs. Level 3	924.500	1	924.500	2.805	.138
	Level 3 vs. Level 4	1326.125	1	1326.125	5.542	.051
	Level 4 vs. Level 5	325.125	1	325.125	3.660	.097
	Level 5 vs. Level 6	45.125	1	45.125	3.595	.100
Error(TIME)	Level 1 vs. Level 2	4000.875	7	571.554		
	Level 2 vs. Level 3	2307.500	7	329.643		
	Level 3 vs. Level 4	1674.875	7	239.268		
	Level 4 vs. Level 5	621.875	7	88.839		
	Level 5 vs. Level 6	87.875	7	12.554		

a. GROUPING = trained

GROUPING = untrained

Tests of Within-Subjects Contrasts[a]

Measure: MEASURE_1

Source	TIME	Type III Sum of Squares	df	Mean Square	F	Sig.
TIME	Level 1 vs. Level 2	2812.500	1	2812.500	8.057	.025
	Level 2 vs. Level 3	32.000	1	32.000	.066	.804
	Level 3 vs. Level 4	162.000	1	162.000	2.726	.143
	Level 4 vs. Level 5	136.125	1	136.125	.391	.551
	Level 5 vs. Level 6	325.125	1	325.125	13.397	.008
Error(TIME)	Level 1 vs. Level 2	2443.500	7	349.071		
	Level 2 vs. Level 3	3376.000	7	482.286		
	Level 3 vs. Level 4	416.000	7	59.429		
	Level 4 vs. Level 5	2434.875	7	347.839		
	Level 5 vs. Level 6	169.875	7	24.268		

a. GROUPING = untrained

CIR

GROUPING = trained

Tests of Within-Subjects Contrasts[a]

Measure: MEASURE_1

Source	TIME	Type III Sum of Squares	df	Mean Square	F	Sig.
TIME	Level 1 vs. Level 2	.401	1	.401	5.324	.054
	Level 2 vs. Level 3	1.280E-02	1	1.280E-02	.099	.762
	Level 3 vs. Level 4	1.008	1	1.008	7.640	.028
	Level 4 vs. Level 5	.198	1	.198	1.242	.302
	Level 5 vs. Level 6	.252	1	.252	1.186	.312
	Level 6 vs. Level 7	5.000E-05	1	5.000E-05	.001	.982
	Level 7 vs. Level 8	.120	1	.120	1.519	.258
Error(TIME)	Level 1 vs. Level 2	.527	7	7.523E-02		
	Level 2 vs. Level 3	.907	7	.130		
	Level 3 vs. Level 4	.924	7	.132		
	Level 4 vs. Level 5	1.118	7	.160		
	Level 5 vs. Level 6	1.488	7	.213		
	Level 6 vs. Level 7	.675	7	9.636E-02		
	Level 7 vs. Level 8	.553	7	7.902E-02		

a. GROUPING = trained

GROUPING = untrained

Tests of Within-Subjects Contrasts[a]

Measure: MEASURE_1

Source	TIME	Type III Sum of Squares	df	Mean Square	F	Sig.
TIME	Level 1 vs. Level 2	2.122	1	2.122	6.740	.036
	Level 2 vs. Level 3	8.000E-02	1	8.000E-02	1.412	.273
	Level 3 vs. Level 4	1.862	1	1.862	35.979	.001
	Level 4 vs. Level 5	7.200E-03	1	7.200E-03	.134	.725
	Level 5 vs. Level 6	.485	1	.485	1.512	.259
	Level 6 vs. Level 7	.177	1	.177	.427	.534
	Level 7 vs. Level 8	3.125E-02	1	3.125E-02	.791	.403
Error(TIME)	Level 1 vs. Level 2	2.204	7	.315		
	Level 2 vs. Level 3	.397	7	5.666E-02		
	Level 3 vs. Level 4	.362	7	5.176E-02		
	Level 4 vs. Level 5	.375	7	5.360E-02		
	Level 5 vs. Level 6	2.246	7	.321		
	Level 6 vs. Level 7	2.900	7	.414		
	Level 7 vs. Level 8	.277	7	3.951E-02		

a. GROUPING = untrained

Change in FANG

GROUPING = trained

Tests of Within-Subjects Contrasts[a]

Measure: MEASURE_1

Source	TIME	Type III Sum of Squares	df	Mean Square	F	Sig.
TIME	Level 1 vs. Level 2	603.781	1	603.781	34.370	.001
	Level 2 vs. Level 3	19.531	1	19.531	9.289	.019
	Level 3 vs. Level 4	81.281	1	81.281	6.153	.042
	Level 4 vs. Level 5	12.500	1	12.500	1.496	.261
	Level 5 vs. Level 6	22.781	1	22.781	20.012	.003
	Level 6 vs. Level 7	11.281	1	11.281	2.635	.149
	Level 7 vs. Level 8	3.125	1	3.125	1.636	.242
Error(TIME)	Level 1 vs. Level 2	122.969	7	17.567		
	Level 2 vs. Level 3	14.719	7	2.103		
	Level 3 vs. Level 4	92.469	7	13.210		
	Level 4 vs. Level 5	58.500	7	8.357		
	Level 5 vs. Level 6	7.969	7	1.138		
	Level 6 vs. Level 7	29.969	7	4.281		
	Level 7 vs. Level 8	13.375	7	1.911		

a. GROUPING = trained

GROUPING = untrained

Tests of Within-Subjects Contrasts[a]

Measure: MEASURE_1

Source	TIME	Type III Sum of Squares	df	Mean Square	F	Sig.
TIME	Level 1 vs. Level 2	693.781	1	693.781	51.958	.000
	Level 2 vs. Level 3	116.281	1	116.281	6.619	.037
	Level 3 vs. Level 4	13.781	1	13.781	3.330	.111
	Level 4 vs. Level 5	21.125	1	21.125	.389	.552
	Level 5 vs. Level 6	1.531	1	1.531	.090	.773
	Level 6 vs. Level 7	3.125	1	3.125	.306	.597
	Level 7 vs. Level 8	7.031	1	7.031	1.991	.201
Error(TIME)	Level 1 vs. Level 2	93.469	7	13.353		
	Level 2 vs. Level 3	122.969	7	17.567		
	Level 3 vs. Level 4	28.969	7	4.138		
	Level 4 vs. Level 5	379.875	7	54.268		
	Level 5 vs. Level 6	119.219	7	17.031		
	Level 6 vs. Level 7	71.375	7	10.196		
	Level 7 vs. Level 8	24.719	7	3.531		

a. GROUPING = untrained

Change in RANG

GROUPING = trained

Tests of Within-Subjects Contrasts[a]

Measure: MEASURE_1

Source	TIME	Type III Sum of Squares	df	Mean Square	F	Sig.
TIME	Level 1 vs. Level 2	36.125	1	36.125	3.186	.117
	Level 2 vs. Level 3	.281	1	.281	.088	.776
	Level 3 vs. Level 4	5.281	1	5.281	.428	.534
	Level 4 vs. Level 5	24.500	1	24.500	1.545	.254
	Level 5 vs. Level 6	21.125	1	21.125	2.670	.146
	Level 6 vs. Level 7	28.125	1	28.125	3.431	.106
	Level 7 vs. Level 8	.281	1	.281	.030	.867
Error(TIME)	Level 1 vs. Level 2	79.375	7	11.339		
	Level 2 vs. Level 3	22.469	7	3.210		
	Level 3 vs. Level 4	86.469	7	12.353		
	Level 4 vs. Level 5	111.000	7	15.857		
	Level 5 vs. Level 6	55.375	7	7.911		
	Level 6 vs. Level 7	57.375	7	8.196		
	Level 7 vs. Level 8	65.469	7	9.353		

a. GROUPING = trained

GROUPING = untrained

Tests of Within-Subjects Contrasts[a]

Measure: MEASURE_1

Source	TIME	Type III Sum of Squares	df	Mean Square	F	Sig.
TIME	Level 1 vs. Level 2	258.781	1	258.781	3.192	.117
	Level 2 vs. Level 3	94.531	1	94.531	2.349	.169
	Level 3 vs. Level 4	144.500	1	144.500	12.565	.009
	Level 4 vs. Level 5	21.125	1	21.125	1.712	.232
	Level 5 vs. Level 6	351.125	1	351.125	2.452	.161
	Level 6 vs. Level 7	5.281	1	5.281	.038	.852
	Level 7 vs. Level 8	60.500	1	60.500	2.672	.146
Error(TIME)	Level 1 vs. Level 2	567.469	7	81.067		
	Level 2 vs. Level 3	281.719	7	40.246		
	Level 3 vs. Level 4	80.500	7	11.500		
	Level 4 vs. Level 5	86.375	7	12.339		
	Level 5 vs. Level 6	1002.375	7	143.196		
	Level 6 vs. Level 7	985.469	7	140.781		
	Level 7 vs. Level 8	158.500	7	22.643		

a. GROUPING = untrained

Plasma CK concentration

GROUPING = trained

Tests of Within-Subjects Contrasts[a]

Measure: MEASURE_1

Source	TIME	Type III Sum of Squares	df	Mean Square	F	Sig.
TIME	Level 1 vs. Level 2	138603.571	1	138603.571	2.358	.176
	Level 2 vs. Level 3	102003.571	1	102003.571	4.159	.088
	Level 3 vs. Level 4	497422.286	1	497422.286	1.363	.287
	Level 4 vs. Level 5	9509.143	1	9509.143	.202	.669
	Level 5 vs. Level 6	81001.286	1	81001.286	.815	.401
Error(TIME)	Level 1 vs. Level 2	352669.429	6	58778.238		
	Level 2 vs. Level 3	147151.429	6	24525.238		
	Level 3 vs. Level 4	2189051.714	6	364841.952		
	Level 4 vs. Level 5	282948.857	6	47158.143		
	Level 5 vs. Level 6	596069.714	6	99344.952		

a. GROUPING = trained

GROUPING = untrained

Tests of Within-Subjects Contrasts[a]

Measure: MEASURE_1

Source	TIME	Type III Sum of Squares	df	Mean Square	F	Sig.
TIME	Level 1 vs. Level 2	936190.861	1	936190.861	2.705	.144
	Level 2 vs. Level 3	1974481.920	1	1974481.920	.800	.401
	Level 3 vs. Level 4	3723174.720	1	3723174.720	2.310	.172
	Level 4 vs. Level 5	5970240.125	1	5970240.125	2.062	.194
	Level 5 vs. Level 6	1407842.000	1	1407842.000	1.584	.249
Error(TIME)	Level 1 vs. Level 2	2422865.829	7	346123.690		
	Level 2 vs. Level 3	17282961.4	7	2468994.491		
	Level 3 vs. Level 4	11282029.0	7	1611718.434		
	Level 4 vs. Level 5	20270910.9	7	2895844.411		
	Level 5 vs. Level 6	6221608.000	7	888801.143		

a. GROUPING = untrained

Appendix G

Planned comparison T-tests

Isometric 90° Torque

Group Statistics

	GROUPING	N	Mean	Std. Deviation	Std. Error Mean
DAY1	trained	8	81.9069	10.0737	3.5616
	untrained	8	60.7964	11.1499	3.9421
DAY3	trained	8	89.4425	9.5183	3.3652
	untrained	7	65.9487	22.0391	8.3300
DAY5	trained	8	92.8644	9.0220	3.1898
	untrained	8	76.1794	24.3500	8.6090

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
DAY1	Equal variances assumed	.273	.609	3.974	14	.001	21.1105	5.3127	9.7159	32.5052
	Equal variances not assumed			3.974	13.858	.001	21.1105	5.3127	9.7049	32.5161
DAY3	Equal variances assumed	3.934	.069	2.748	13	.017	23.4938	8.5507	5.0210	41.9666
	Equal variances not assumed			2.615	7.937	.031	23.4938	8.9841	2.7478	44.2398
DAY5	Equal variances assumed	5.328	.037	1.817	14	.091	16.6850	9.1809	-3.0062	36.3761
	Equal variances not assumed			1.817	8.886	.103	16.6850	9.1809	-4.1243	37.4942

Isometric 150° Torque

Group Statistics

	GROUPING	N	Mean	Std. Deviation	Std. Error Mean
DAY1	trained	8	77.6734	13.9504	4.9322
	untrained	8	63.2342	14.9435	5.2833
DAY3	trained	8	85.0364	12.7299	4.5007
	untrained	7	65.1858	21.7988	8.2392
DAY5	trained	8	91.0167	16.3905	5.7949
	untrained	8	66.5065	24.6931	8.7303

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
DAY1	Equal variances assumed	.191	.669	1.998	14	.066	14.4391	7.2277	-1.0628	29.9411
	Equal variances not assumed			1.998	13.934	.066	14.4391	7.2277	-1.0697	29.9480
DAY3	Equal variances assumed	1.191	.295	2.191	13	.047	19.8507	9.0619	.2736	39.4278
	Equal variances not assumed			2.114	9.398	.062	19.8507	9.3883	-1.2509	40.9523
DAY5	Equal variances assumed	1.530	.236	2.339	14	.035	24.5102	10.4785	2.0360	46.9844
	Equal variances not assumed			2.339	12.166	.037	24.5102	10.4785	1.7139	47.3065

30°/second Torque

Group Statistics

	GROUPING	N	Mean	Std. Deviation	Std. Error Mean
DAY1	trained	8	83.7803	16.2437	5.7430
	untrained	8	62.6709	12.0592	4.2636
DAY3	trained	8	90.8319	19.1897	6.7846
	untrained	8	71.3426	14.3094	5.0592
DAY5	trained	8	98.8707	16.4000	5.7983
	untrained	8	72.1709	15.1429	5.3538

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
DAY1	Equal variances assumed	.181	.677	2.951	14	.011	21.1094	7.1527	5.7685	36.4503
	Equal variances not assumed			2.951	12.918	.011	21.1094	7.1527	5.6471	36.5717
DAY3	Equal variances assumed	.222	.645	2.303	14	.037	19.4893	8.4632	1.3375	37.6411
	Equal variances not assumed			2.303	12.946	.039	19.4893	8.4632	1.1979	37.7807
DAY5	Equal variances assumed	.018	.896	3.383	14	.004	26.6997	7.8920	9.7731	43.6263
	Equal variances not assumed			3.383	13.912	.004	26.6997	7.8920	9.7630	43.6364

90°/second Torque

Group Statistics

	GROUPING	N	Mean	Std. Deviation	Std. Error Mean
DAY1	trained	8	82.0414	17.3453	6.1325
	untrained	8	61.6287	12.2609	4.3349
DAY3	trained	8	93.8184	22.4708	7.9446
	untrained	8	74.4168	19.8002	7.0004
DAY5	trained	8	101.6637	26.5082	9.3721
	untrained	8	76.2908	19.5369	6.9073

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
DAY1	Equal variances assumed	.663	.429	2.718	14	.017	20.4127	7.5099	4.3056	36.5198
	Equal variances not assumed			2.718	12.598	.018	20.4127	7.5099	4.1357	36.6897
DAY3	Equal variances assumed	.178	.680	1.832	14	.088	19.4016	10.5888	-3.3092	42.1123
	Equal variances not assumed			1.832	13.782	.089	19.4016	10.5888	-3.3429	42.1461
DAY5	Equal variances assumed	.365	.556	2.179	14	.047	25.3730	11.6425	.4024	50.3436
	Equal variances not assumed			2.179	12.872	.048	25.3730	11.6425	.1955	50.5504

150°/second Torque

Group Statistics

	GROUPING	N	Mean	Std. Deviation	Std. Error Mean
DAY1	trained	8	82.9246	18.6777	6.6036
	untrained	8	65.4929	17.4440	6.1674
DAY3	trained	8	92.4033	21.4846	7.5959
	untrained	8	71.4628	20.4478	7.2294
DAY5	trained	8	94.1014	21.6483	7.6538
	untrained	8	83.5162	26.1419	9.2426

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
DAY1	Equal variances assumed	.153	.702	1.929	14	.074	17.4318	9.0357	-1.9479	36.8114
	Equal variances not assumed			1.929	13.935	.074	17.4318	9.0357	-1.9563	36.8199
DAY3	Equal variances assumed	.002	.969	1.997	14	.066	20.9405	10.4863	-1.5504	43.4313
	Equal variances not assumed			1.997	13.966	.066	20.9405	10.4863	-1.5555	43.4365
DAY5	Equal variances assumed	.302	.591	.882	14	.393	10.5852	12.0003	-15.1528	36.3232
	Equal variances not assumed			.882	13.530	.393	10.5852	12.0003	-15.2369	36.4074

210°/second Torque

Group Statistics

	GROUPING	N	Mean	Std. Deviation	Std. Error Mean
DAY1	trained	8	88.3237	16.5963	5.8677
	untrained	8	68.8267	17.4801	6.1802
DAY3	trained	8	95.8316	24.3772	8.6186
	untrained	8	70.5827	22.7823	8.0548
DAY5	trained	8	100.9076	25.7307	9.0972
	untrained	7	79.2574	30.2196	11.4219

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
DAY1	Equal variances assumed	.365	.555	2.288	14	.038	19.4970	8.5220	1.2192	37.7748
	Equal variances not assumed			2.288	13.962	.038	19.4970	8.5220	1.2146	37.7794
DAY3	Equal variances assumed	.025	.876	2.140	14	.050	25.2489	11.7966	-5.24E-02	50.5501
	Equal variances not assumed			2.140	13.936	.051	25.2489	11.7966	-6.32E-02	50.5609
DAY5	Equal variances assumed	.081	.780	1.500	13	.158	21.6502	14.4357	-9.5362	52.8366
	Equal variances not assumed			1.483	11.916	.164	21.6502	14.6020	-10.1896	53.4900

300°/second Torque

Group Statistics

	GROUPING	N	Mean	Std. Deviation	Std. Error Mean
DAY1	trained	8	88.6436	18.0747	6.3904
	untrained	8	67.2533	16.6532	5.8878
DAY3	trained	8	93.9372	25.0575	8.8592
	untrained	8	74.8393	22.4787	7.9474
DAY5	trained	8	102.0410	29.2984	10.3585
	untrained	8	84.4360	28.7646	10.1698

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
DAY1	Equal variances assumed	.006	.938	2.462	14	.027	21.3903	8.6892	2.7538	40.0269
	Equal variances not assumed			2.462	13.907	.028	21.3903	8.6892	2.7421	40.0386
DAY3	Equal variances assumed	.006	.941	1.605	14	.131	19.0979	11.9015	-6.4284	44.6241
	Equal variances not assumed			1.605	13.838	.131	19.0979	11.9015	-6.4565	44.6522
DAY5	Equal variances assumed	.046	.832	1.213	14	.245	17.6049	14.5163	-13.5295	48.7394
	Equal variances not assumed			1.213	13.995	.245	17.6049	14.5163	-13.5305	48.7404

Extension SOR

Group Statistics

	GROUPING	N	Mean	Std. Deviation	Std. Error Mean
DAY1	trained	8	24.13	28.21	9.97
	untrained	8	17.63	12.83	4.54
DAY3	trained	8	10.00	12.28	4.34
	untrained	8	25.00	22.65	8.01
DAY5	trained	8	1.13	1.89	.67
	untrained	8	19.75	30.51	10.79

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
DAY1	Equal variances assumed	3.884	.069	.593	14	.562	6.50	10.96	-17.00	30.00
	Equal variances not assumed			.593	9.776	.566	6.50	10.96	-17.99	30.99
DAY3	Equal variances assumed	1.338	.267	-1.646	14	.122	-15.00	9.11	-34.54	4.54
	Equal variances not assumed			-1.646	10.788	.128	-15.00	9.11	-35.10	5.10
DAY5	Equal variances assumed	18.000	.001	-1.723	14	.107	-18.63	10.81	-41.80	4.55
	Equal variances not assumed			-1.723	7.053	.128	-18.63	10.81	-44.14	6.89

Flexion SOR

Group Statistics

	GROUPING	N	Mean	Std. Deviation	Std. Error Mean
DAY1	trained	8	7.88	7.47	2.64
	untrained	8	9.13	9.92	3.51
DY3	trained	8	3.38	3.85	1.36
	untrained	8	14.63	20.83	7.36
DAY5	trained	8	1.3750	1.9955	.7055
	untrained	8	7.3750	14.7158	5.2028

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
DAY1	Equal variances assumed	.084	.776	-.285	14	.780	-1.25	4.39	-10.67	8.17
	Equal variances not assumed			-.285	13.009	.780	-1.25	4.39	-10.74	8.24
DY3	Equal variances assumed	10.929	.005	-1.502	14	.155	-11.25	7.49	-27.31	4.81
	Equal variances not assumed			-1.502	7.478	.174	-11.25	7.49	-28.73	6.23
DAY5	Equal variances assumed	3.632	.077	-1.143	14	.272	-6.0000	5.2504	-17.2610	5.2610
	Equal variances not assumed			-1.143	7.257	.289	-6.0000	5.2504	-18.3266	6.3266

Upper arm SOR

Group Statistics

	GROUPING	N	Mean	Std. Deviation	Std. Error Mean
DAY1	trained	8	83.38	43.11	15.24
	untrained	8	61.75	46.87	16.57
DAY3	trained	8	67.13	50.10	17.71
	untrained	8	90.75	73.63	26.03
DAY5	trained	8	14.00	16.73	5.92
	untrained	8	55.88	58.03	20.52

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
DAY1	Equal variances assumed	.008	.930	.960	14	.353	21.63	22.51	-26.66	69.91
	Equal variances not assumed			.960	13.903	.353	21.63	22.51	-26.70	69.95
DAY3	Equal variances assumed	1.822	.199	-.750	14	.466	-23.63	31.49	-91.16	43.91
	Equal variances not assumed			-.750	12.338	.467	-23.63	31.49	-92.02	44.77
DAY5	Equal variances assumed	7.879	.014	-1.961	14	.070	-41.88	21.35	-87.67	3.92
	Equal variances not assumed			-1.961	8.156	.085	-41.88	21.35	-90.95	7.20

Forearm SOR

Group Statistics

	GROUPING	N	Mean	Std. Deviation	Std. Error Mean
DAY1	trained	8	34.88	23.91	8.45
	untrained	8	18.75	18.68	6.61
DAY3	trained	8	11.25	10.69	3.78
	untrained	8	25.25	16.71	5.91
DAY5	trained	8	2.50	4.84	1.71
	untrained	8	14.75	21.35	7.55

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
DAY1	Equal variances assumed	1.740	.208	1.503	14	.155	16.13	10.73	-6.88	39.13
	Equal variances not assumed			1.503	13.227	.156	16.13	10.73	-7.01	39.26
DAY3	Equal variances assumed	2.112	.163	-1.996	14	.066	-14.00	7.01	-29.04	1.04
	Equal variances not assumed			-1.996	11.904	.069	-14.00	7.01	-29.30	1.30
DAY5	Equal variances assumed	10.470	.006	-1.583	14	.136	-12.25	7.74	-28.85	4.35
	Equal variances not assumed			-1.583	7.718	.154	-12.25	7.74	-30.21	5.71

CIR

Group Statistics

	GROUPING	N	Mean	Std. Deviation	Std. Error Mean
DAY1	trained	8	101.8059	1.4687	.5193
	untrained	8	103.1962	1.1994	.4241
DAY3	trained	8	100.6828	2.1993	.7776
	untrained	8	104.2364	3.3081	1.1696
DAY5	trained	8	101.0456	1.2769	.4515
	untrained	8	105.1162	4.9050	1.7342

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
DAY1	Equal variances assumed	1.005	.333	-2.074	14	.057	-1.3904	.6704	-2.8283	4.756E-02
	Equal variances not assumed			-2.074	13.462	.058	-1.3904	.6704	-2.8337	5.297E-02
DAY3	Equal variances assumed	.663	.429	-2.530	14	.024	-3.5536	1.4045	-6.5659	-.5412
	Equal variances not assumed			-2.530	12.176	.026	-3.5536	1.4045	-6.6088	-.4984
DAY5	Equal variances assumed	6.055	.027	-2.272	14	.039	-4.0705	1.7920	-7.9140	-.2271
	Equal variances not assumed			-2.272	7.944	.053	-4.0705	1.7920	-8.2079	6.683E-02

Change in FANG

Group Statistics

	GROUPING	N	Mean	Std. Deviation	Std. Error Mean
DAY1	trained	8	3.938	3.005	1.063
	untrained	8	6.813	5.587	1.975
DAY3	trained	8	1.000	1.604	.567
	untrained	8	8.000	5.916	2.092
DAY5	trained	8	.438	2.528	.894
	untrained	8	6.438	7.028	2.485

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
DAY1	Equal variances assumed	1.847	.196	-1.282	14	.221	-2.875	2.243	-7.685	1.935
	Equal variances not assumed			-1.282	10.738	.227	-2.875	2.243	-7.826	2.076
DAY3	Equal variances assumed	12.188	.004	-3.230	14	.006	-7.000	2.167	-11.648	-2.352
	Equal variances not assumed			-3.230	8.023	.012	-7.000	2.167	-11.995	-2.005
DAY5	Equal variances assumed	5.737	.031	-2.272	14	.039	-6.000	2.640	-11.663	-.337
	Equal variances not assumed			-2.272	8.781	.050	-6.000	2.640	-11.996	-4.060E-03

Change in RANG

Group Statistics

	GROUPING	N	Mean	Std. Deviation	Std. Error Mean
DAY1	trained	8	-2.750	3.836	1.356
	untrained	8	-6.500	6.211	2.196
DAY3	trained	8	-3.000	3.845	1.359
	untrained	8	-11.500	16.162	5.714
DAY5	trained	8	-.688	1.731	.612
	untrained	8	-9.563	21.291	7.528

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
DAY1	Equal variances assumed	.801	.386	1.453	14	.168	3.750	2.581	-1.785	9.285
	Equal variances not assumed			1.453	11.662	.173	3.750	2.581	-1.891	9.391
DAY3	Equal variances assumed	6.818	.021	1.447	14	.170	8.500	5.874	-4.098	21.098
	Equal variances not assumed			1.447	7.790	.187	8.500	5.874	-5.109	22.109
DAY5	Equal variances assumed	4.082	.063	1.175	14	.260	8.875	7.552	-7.323	25.073
	Equal variances not assumed			1.175	7.093	.278	8.875	7.552	-8.937	26.687

Plasma CK Concentration

Group Statistics

	GROUPING	N	Mean	Std. Deviation	Std. Error Mean
TPRE	trained	8	398.000	283.753	100.322
	untrained	8	163.663	95.589	33.796
TDAY1	trained	7	563.286	271.457	102.601
	untrained	8	505.750	594.454	210.171
TDAY3	trained	8	646.625	663.459	234.568
	untrained	8	1684.750	3381.468	1195.530
TDAY5	trained	8	757.825	973.042	344.022
	untrained	8	2968.125	3904.586	1380.480

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
TPRE	Equal variances assumed	21.985	.000	2.214	14	.044	234.338	105.861	7.287	461.388
	Equal variances not assumed			2.214	8.563	.056	234.338	105.861	-6.988	475.663
TDAY1	Equal variances assumed	.514	.486	.235	13	.818	57.536	245.107	-471.986	587.057
	Equal variances not assumed			.246	10.067	.811	57.536	233.878	-463.107	578.179
TDAY3	Equal variances assumed	3.059	.102	-.852	14	.409	-1038.125	1218.324	-3651.170	1574.920
	Equal variances not assumed			-.852	7.538	.420	-1038.125	1218.324	-3877.831	1801.581
TDAY5	Equal variances assumed	13.762	.002	-1.554	14	.143	-2210.300	1422.700	-5261.688	841.088
	Equal variances not assumed			-1.554	7.866	.160	-2210.300	1422.700	-5500.798	1080.198